PHYSICAL AND CHEMICAL ENVIRONMENTAL FACTORS ASSOCIATED WITH THE TEMPORAL AND SPATIAL DISTRIBUTION OF CYANOBACTERIA IN LAKE GEORGE, NEW YORK

By

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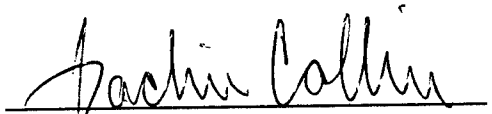

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ABSTRACT

Cyanobacteria and environmental factors were studied in Lake George, New York from May 1998 to August 1998. Lake George, New York is a (meso) oligotrophic freshwater lake located in the southeast corner of the Adirondack State Park. An island filled channel known as The Narrows separates it into two distinct basins. The water in the lake flows from south to north where it empties into Lake Champlain near Ticonderoga, New York. The lake is dimictic, mixing in the spring and the fall, and stratification of the water column into a distinct epilimnion and hypolimnion occurs each summer. The lake undergoes a clear water phase in late May/early June.

The goal of the study was to determine the temporal and spatial development of the cyanobacteria population in the north and south basins of the lake and their association to physical and chemical factors in the water column. Various nitrogen and phosphorus species were measured along with physical factors such as temperature, pH, dissolved oxygen, specific conductance, and illumination. These factors were then used to search for trends and associations with cyanobacteria enumerated by epifluorescent microscopy.

One morphological genus, *Synechococcus*, was found to dominate the cyanobacteria population throughout the water column and throughout the period of the study. Abundance of *Synechococcus* increased after the clear water phase ended, reaching its maximum in both basins in early August. Other general trends showed the greatest initial abundance of *Synechococcus* at 20 and 25 meters in depth in the late spring and this moved up in the water column

to an average of 15 meters after the clear water phase of the lake ended in mid-June. Slight temporal and spatial differences were found between the two sites, however linear regression found no strong associations between *Synechococcus* and any single chemical or physical factor. Multiple linear regression analysis was used to construct statistical models of both sites using all measured chemical and physical factors and these models showed that there were multiple factors associated with *Synechococcus* populations at each site both prior to and after the clear water phase in mid-June.

INTRODUCTION

Cyanobacteria are photosynthetic prokaryotic organisms found in various environments throughout the world. Cyanobacteria are found in three primary shapes, coccoidal, bacillary, and filamentous. Cyanobacteria are autotrophic meaning they can produce their own food, in this case through the process of photosynthesis. Cyanobacteria are part of the phytoplankton of many lakes, reservoirs and oceans and as primary producers they constitute an important part of the food web of these ecosystems. They exist not only in aquatic environments, but also in terrestrial environments. They can also exist in large mats and are found in extreme environments such as hot springs. The planktonic forms of cyanobacteria normally range in size from .5 to 2 microns in diameter for the coccoidal forms (Murphy & Haugen, 1985) and are termed picophytoplankton because of this size dimension. They have also been described as ultraphytoplankton in at least one journal article, indicating phytoplankton with diameters of less than 8 *u*m (Lindell and Post, 1995). Even though they primarily exist as these small unicellular forms in Lake George, they also can reach much longer lengths in various filamentous forms. Cyanobacteria in freshwater environments can also be found in large, gelatinous, colonial communities containing hundreds of picophytoplankton members.

The name Cyanobacteria is derived from the Greek word Kyano meaning dark blue and until recently these organisms were known simply as "blue-green" algae. This name is still found quite often in textbooks and literature, however this "blue-green" axiom applies to only a small portion of what is now classified

as cyanobacteria. Cyanobacteria historically were classified as part of the Plant Kingdom, recently however they have been moved to the Kingdom Prokaryotae as proposed in Bergey's Manual of Systematic Bacteriology, in which they are found in Division I Gracilicutes class Oxyphotobacteria (Henderson's Dictionary of Biological Terms).

Unlike some eukaryotic algae and other higher photosynthetic organisms which use chlorophyll a and b as their light harvesting pigments for photosynthesis, cyanobacteria use primarily phycobiliproteins. The phycobiliprotein associated with the name cyanobacteria, for example, is phycocyanin, which gives the organisms a blue-green appearance. Another important phycobiliprotein often associated with cyanobacteria is phycoerythrin. This pigment gives the cyanobacteria a reddish-pink color. Cyanobacteria still contain chlorophyll a in their photosynthetic reaction centers I and II, but not in as great a concentration as found in eukaryotic algae.

Because of their small size, researchers have had difficulty in the past studying these tiny organisms and were only able to study the larger filamentous forms, such as *Anaebaena* or *Nostoc*. Recent advances in electron and epifluorescent microscopy however have allowed more detailed examinations of the physical structure of the smaller but yet more abundant cyanobacteria generally referred to *Synechococcus* (Albertano et al., 1997). *Synechococcus* are picophytoplankton (size range .5 – 2 *u*m). It is these organisms which are most abundant in Lake George and it is their temporal and spatial distribution that was the focus of this research.

Lake George, New York was the site selected for this study. Lake George is a (meso) oligotrophic freshwater lake located in the southeast corner of the Adirondack State Park in the state of New York, United States of America (see Figure 1). Oligotrophic lakes contain very low concentrations of the nutrients required for the growth of autotrophic organisms. Nutrient concentration levels normally drop to below detection level in the warm surface waters during the summer months, but are detectable in late winter and early spring. Lake George is a dimictic lake meaning it undergoes a spring and fall mixing of surface water and bottom water. It stratifies in the summer forming a metalimnion at approximately 10 to 15 meters with a warm water epilimnion above and a cold water hypolimnion below.

Lake George is long and narrow, running 51 kilometers from the southwestern to the northeastern ends with an average width of 2.2 kilometers, a maximum depth of 57 meters, and an average depth of 21 meters. The lake is divided into two distinct basins, north and south. An island filled channel known as The Narrows separates the two basins. The general flow of the water is from the south basin into the north basin and out near the town of Ticonderoga, New York where it flows into Lake Champlain. The lake surface covers an area of approximately 114 square kilometers and contains 365 islands (Collier, unpublished).

Lake George is considered a pristine lake and is still the principal potable water source for the majority of the rural inhabitants surrounding the lake. Lake George is primarily a recreational lake and is used extensively during the

summer months for boating, skiing, and fishing. Forested areas containing both deciduous and coniferous trees primarily surround Lake George. There are no major agricultural areas draining into the lake, however septic systems are the major waste management systems for the rural residents around the lake. There are several population centers around the lake with the two largest being in the south. Lake George Village is located at the southern end of the south basin and is the center of tourism for Lake George during the summer months. Lake George Village is followed closely in size by the town of Bolton Landing also located on the south basin along the western shore of the lake. Both of these population centers have sewage treatment facilities that empty into Lake George.

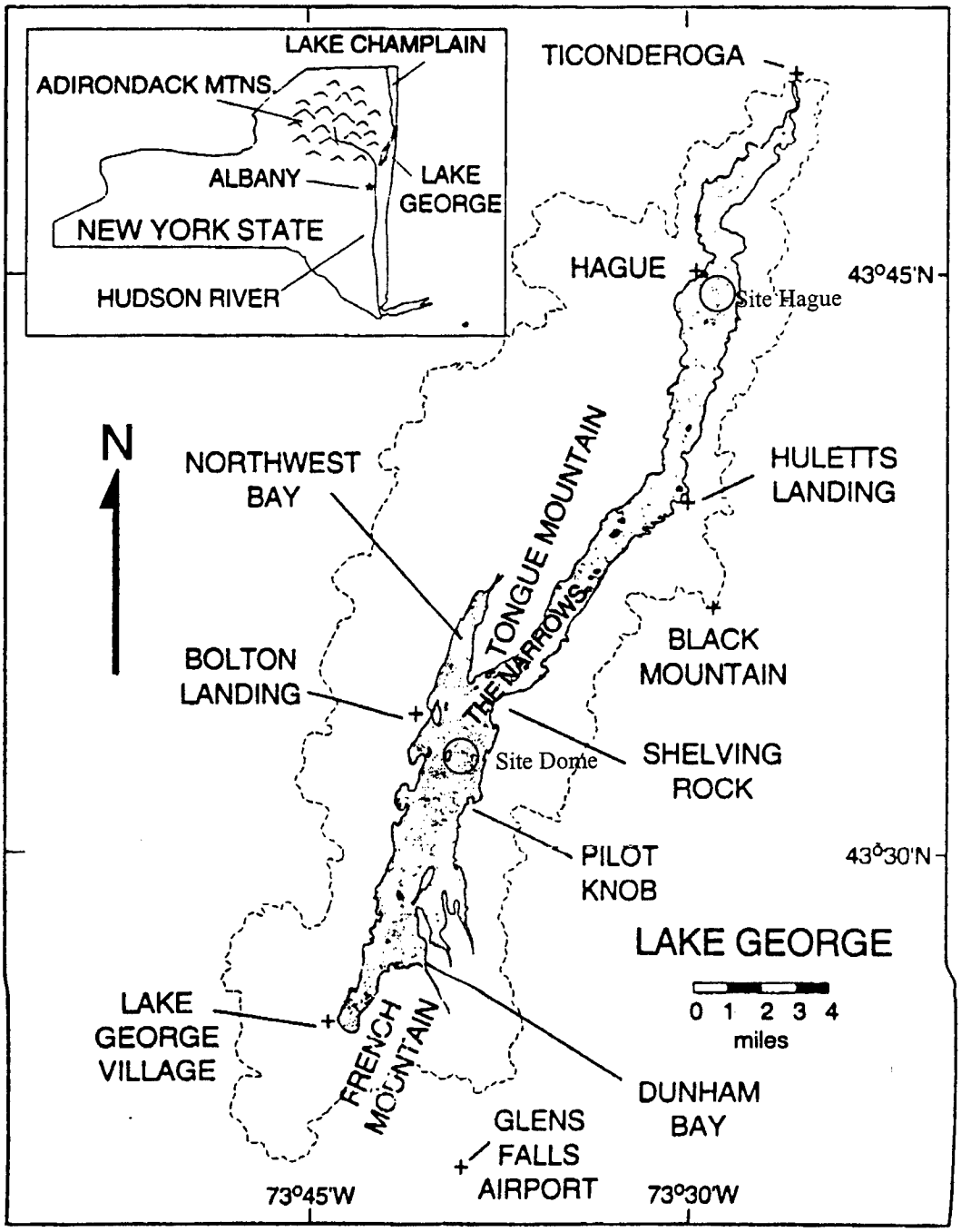
LAKE CHAMPLAIN
ADIRONDACK MTNS.
ALBANY
LAKE GEORGE
NEW YORK STATE
HUDSON RIVER
TICONDEROGA
HAGUE
Site Hague
43°45'N
N
NORTHWEST BAY
TONGUE MOUNTAIN
THE NARROWS
HULETTS LANDING
BLACK MOUNTAIN
BOLTON LANDING
Site Dome
SHELVING ROCK
PILOT KNOB
43°30'N
LAKE GEORGE
0 1 2 3 4
miles
LAKE GEORGE VILLAGE
FRENCH MOUNTAIN
DUNHAM BAY
GLENS FALLS AIRPORT
73°45'W
73°30'W

Figure 1

HISTORICAL REVIEW

John Waterbury from Woods Hole Oceanographic Institute was the first to report the widespread occurrence of small, marine, chroococcalean cyanobacteria belonging to the genus *Synechococcus* (Waterbury, 1979). Since that time other researchers have found these small organisms existing in the euphotic zones of the oceans and seas (Olsen et al., 1990; Lindell and Post, 1995; Agawin and Agusti, 1997; Albertano et al., 1997; Li, 1998) and other researchers have found them existing in large populations in freshwater environments (Caron et al., 1985; Fahnensteihl et al. 1991). In the euphotic zone of the North Atlantic *Synechococcus* have been found to exist at a frequency of 10^7-10^8 cells per liter (Murphy & Haugen, 1985) and in freshwater systems such as Lake Ontario in concentrations as great as 6.5×10^5 cells per milliliter (Caron et al., 1985). These scientific papers show that these small organisms exist in large numbers in diversified environments, yet very little research has been done in freshwater systems to better understand their place in the ecosystem. Until this study no significant research had been conducted on these small yet numerous organisms in Lake George, New York.

As primary producers, *Synechococcus* represent an integral part of the base of an intricate and delicately balanced microbial food web containing other organisms such as heterotrophic nanoflagellates, ciliates, and zooplankton. Since *Synechococcus* along with other primary producers represent the base of this microbial food web it is important to understand the chemical and physical conditions that are associated with the abundance of these organisms.

Synechococcus, like other photosynthetic organisms, require light and nutrients. *Synechococcus* contain chlorophyll a as their primary photosynthetic pigment along with the phycobiliprotein phycoerythrin as the principle light-harvesting pigment (Waterbury et al, 1987) which gives them a reddish-pink color to the naked eye. Phycoerythrin fluoresces orange under green light epifluorescence and it is this characteristic that allows for their enumeration with an epifluorescent microscope (Albertano et al., 1997).

The nutrients required for *Synechococcus* reproduction and growth (along with other photoautotrophs) that are present in the water column and available for use by *Synechococcus* enter in various biogeochemical ways such as atmospheric deposition, geological weathering, or decomposition of organic matter. Continuing research and monitoring by the Darrin Freshwater Institute at Lake George has provided important information on many of these important nutrients and their association to chlorophyll a concentrations and Secchi Disk depths (Momen et al., 1996). None of these studies however have addressed the associations of these nutrients along with other chemical and physical factors to *Synechococcus* populations or any other specific phytoplankton population.

Two principal nutrients required by photosynthetic organisms whether they are fresh-water or marine organisms are nitrogen and phosphorus. These nutrients are important to many intracellular processes, such as amino acid formation and DNA replication. Examples of nitrogenous forms are urea, ammonium, nitrate, and nitrite. All of these are potential sources of nitrogen for *Synechococcus*, and represent only a small portion of the total nitrogen found in

the water column. Some cyanobacteria have a capability to fix nitrogen (N_2) directly from the atmosphere and use this nitrogen in their metabolic processes. At present there is no evidence that the *Synechococcus* in Lake George have this capability.

The other critical nutrient is phosphorus, which is found in extremely low concentrations in most freshwater ecosystems. In fact the current limnological dogma is that nitrogen limits growth of phytoplankton in the ocean, but phosphorus limits phytoplankton growth in freshwater systems (Smith, 1984). The word limiting is used here in accordance with Liebig's Law of the Minimum which states that the food element (i.e., nutrient) least plentiful in proportion to the requirements of plants limits their growth. This is a simplistic model and many other factors can control the decline or succession of a particular species of organism in an ecosystem. Recent research in Lake Champlain also indicates a more intricate nutrient relationship for phytoplankton then simply assuming it is always phosphorus that limits growth (Levine et al., 1997). At present phosphorus is considered by some to be the limiting nutrient in Lake George.

Even with *Synechococcus* ' crucial role in aquatic food webs, little is known about their community and ecological dynamics. Most research in the past has focused on the marine *Synechococcus* and somewhat less on the freshwater *Synechococcus*. Some research has been done to study the temporal and spatial conditions associated with the populations of *Synechococcus* in freshwater lakes and reservoirs (Caron et al., 1985; Fahnenstiel, et al., 1991).

Normally cyanobacteria are associated with algal "blooms" in lakes and also with the process of eutrophication. Eutrophication is the enrichment of bodies of fresh water by inorganic plant nutrients such as phosphorus and nitrogen that lead to increases in phytoplankton and zooplankton populations. This process also leads to a decrease in species diversity caused increasing anaerobic conditions in the water column and through time leads to the transition to dry land (Henderson's Dictionary of Biological Terms). This process occurs under normal environmental conditions, but the increased nutrients added to a watershed by anthropogenic allocthonous sources accelerates the process.

How nutrient concentrations along with other physical conditions such as temperature, pH, and light intensity are associated with the population dynamics of *Synechococcus* is an interesting area of research and will provide critical information to the understanding of the nature of aquatic ecosystems. It is important that we learn as much as possible how natural and man-made processes can affect these population dynamics.

MATERIALS AND METHODS

Description of the Study Site - Two study sites at Lake George were selected. The first site was in the north basin of Lake George approximately 500 meters southeast of the town of Hague and is referred to in this paper as Site Hague (see Figure 1). The second site was approximately 200 meters east of Dome Island in the southern basin and is referred to as Site Dome (see Figure 1). Sites were selected in order to compare and contrast the similarities and differences between the Cyanobacteria populations and the factors associated with their temporal and spatial dynamics in the two basins. Bathymetry data was also studied prior to selecting these two sites in order to find depths suitable for measurements down to 30 meters (Boylen, 1981).

This research would not have been achieved without the support and equipment of the Darrin Freshwater Institute (DFWI) at Lake George, New York. DFWI provided exceptional laboratory facilities along with the transportation and equipment means to facilitate this study.

Research Strategy - Measurements were carried out over a four-month period starting on 04 May 1998 and continuing until 17 August 1998. Initially sampling was conducted weekly from the period 04 May 1998 until 30 Jun 98 and sampling was conducted every two weeks for the remainder of the sampling period. Sampling was conducted during the morning hours normally between the hours of 0730 and 1200. Upon arriving on station and anchoring in 30 meters of water, the first measurement taken was the Secchi Disk Depth which is the measure of water clarity in the lake. The Secchi Disk Depth was monitored at

each site throughout the sampling period using a standard twenty-centimeter diameter Secchi Depth Disk. Secchi Disk Depths were taken on the shady side of the boat. The Secchi Depth Disk was lowered into the water until it could no longer be seen and was then raised until it once again could be seen. The rope used to lower the Secchi Depth Disk was marked at one-meter intervals with black tape. These markings were used to estimate the depth of the Secchi Disk.

A Yellow Springs Instrument Model 610-D was then used to conduct physical measurements of the water column at one-meter intervals from the surface down to 30 meters. A meter was initially provided for use by the Darrin Freshwater Institute, but after the June 15th sampling date a new YSI meter was used for the duration of the sampling period. The YSI probe was lowered over the side of the boat and allowed to stabilize prior to taking measurements. The YSI meter provided accurate temperature, pH, specific conductance, and dissolved oxygen measurements. This process was conducted at each site and measurements were recorded on station during the duration of the actual measurements. Light data, to include surface measurements, depth measurements, and percent light reaching a depth, were also collected and recorded at one meter intervals from the surface to 28 meters in depth on each sampling date using a LICOR LI100 Light Meter. In this case special care was taken to insure that the light probe was lowered over the sunny side of the boat and that nothing shaded the surface sensor placed on the deck of the boat.

Two-liter water samples were collected at 6 five-meter intervals starting at the surface and going down to 25 meters using a one-liter General Oceanics, Inc

Model 1010C Niskin Non-Metallic Convertible Water Sampling Bottle. The water for each depth was collected as two one-liter casts and then the two liters were mixed together prior to separating into sample bottles. The water collected in this manner was used for nutrient assays, cyanobacteria enumeration, and also chlorophyll a/phaeophytin measurements.

The nutrient assays were conducted to ascertain the concentrations of urea, ammonium (NH_4), nitrite (NO_2), nitrate (NO_3), total nitrogen (TN), dissolved nitrogen (DN), orthophosphate (PO_4), total phosphorus (TP), and dissolved phosphorus (DP). Chlorophyll a (Chl a) and phaeophytin (phaeo) concentrations were also measured using a Turner TD-700 Fluorometer with blue light excitation. Cyanobacteria enumeration was conducted using a Zeiss Axioskop w/HBO 100 WZ epifluorescence microscope with green light excitation.

Laboratory Methods (Nutrient Concentration Measurements) -

Upon completion of the field sampling, water samples collected were transported to the Darrin Fresh Water Institute at Lake George for filtering and analysis. The water samples were kept refrigerated or on ice during the entire period after collection and throughout the transport back to Rensselaer Polytechnic Institute in Troy, New York.

Urea concentrations were measured using the Koroleff method for urea analysis outlined in Grasshoff's Methods of Seawater Analysis (Grasshoff, 1983). The analysis is a colorimetric analysis and was conducted utilizing five-centimeter glass cuvettes and measuring absorption at 540 nanometers with a Shimadzu UV-2401 PC UV/VIS Recording Spectrophotometer. Reagent

preparations can be found in Grasshoff's manual, however amounts prepared were smaller than prescribed because smaller samples (5 milliliters) were used instead of the 50-milliliter samples called for in Grasshof's. This was done in order to reduce the amount of hazardous waste produced during the assay procedure. Blanks and standards were treated to the same conditions as the samples throughout the examination. Samples were prepared and measured in triplicate.

Ammonium concentrations were measured using the Koroleff method for ammonium analysis outlined in Grasshoff's Methods of Seawater Analysis (Grasshoff, 1983). This analysis is also a colorometric analysis and it was also conducted using five-centimeter cuvettes at 630 nanometers using the Shimadzu UV-2401 PC UV/VIS Recording Spectrophotometer. Reagents and procedures for this assay can be found in Grasshoff's. As in the urea measurement, five-milliliter samples were used to reduce hazardous waste and triplicates of each sample were measured.

Orthophosphate concentrations were measured using the molybdate reactive phosphate method provided by Jennifer Slater (Director, Keck Water Research Laboratory, Rensselaer Polytechnic Institute) and detailed in Parsons' guide for chemical analysis (Parsons, 1984). This analysis was conducted using 10-centimeter cuvettes at 880 nanometers on the Milton Roy Spectronic spectrophotometer located in the Keck Water Research Laboratory at Rensselaer Polytechnic Institute. Triplicate samples were measured using this procedure. Reagents and procedures can be found in Parson's guide.

Nitrite and nitrate concentrations were measured using QuickChem Method 10-107-04-1-B and the Latchat Autoanalyzer located in the Keck Water Research Laboratory at Rensselaer Polytechnic Institute. Reagents and procedures are outlined in the Latchat instruction manual Method 10-107-04-1-B.

Total Nitrogen and Dissolved Nitrogen concentrations were measured using a method provided by Jennifer Slater, Director of the Keck Water Research Laboratory at Rensselaer Polytechnic Institute. The only difference in the measurement techniques for these two procedures was that the water used for the dissolved nitrogen assay was first prefiltered through a Poretics Products .4 *u*m 47mm-membrane filter.

There are two steps involved in the total nitrogen and dissolved nitrogen measurements. First, the ammonia and organic nitrogen are converted to nitrate by a digestion procedure and this is then followed by the measurement of the nitrate produced.

Standards were made up in concentrations from .1 mg/L to 3.0 mg/L using Potassium nitrate as the NO_3 source. The alkaline persulfate reagent was made using 9 grams sodium hydroxide and 650 grams low-nitrogen potassium persulfate dissolved in one liter of deionized distilled water. This reagent was made fresh prior to each assay run. 25 milliliters of the sample water from Lake George was poured into a clean glass tube and 5 milliliters of the persulfate reagent was added to each tube. Sample and standards were all treated using the same procedures. The samples were measured in triplicate. After adding the reagent the glass tubes were capped carefully with aluminum foil and

autoclaved for 35 minutes at 250^0F and 15 lbs. per in^2. After the autoclave oxidation procedure the samples were allowed to cool and .3 milliliters of 1N hydrochloric acid was added to reduce interference by hydroxyl groups and carbonate ions. The samples were then measured at a wavelength of 220 nanometers utilizing the one-centimeter quartz cuvettes on the Shimadzu UV-2401PC UV/VIS Recording Spectrophotometer. Dissolved nitrogen concentration measurements were conducted utilizing the same procedures with the exception of the prefiltering already discussed.

Total and dissolved phosphorus concentrations were determined similar to the total nitrogen/ dissolved nitrogen concentrations. Once again the only difference in the two assays was that the water used in the dissolved phosphorus assay was prefiltered through a Poretics Products .4 *u*m 47mm-membrane filter. This is also a two step procedure in which all the phosphorus is initially oxidized to orthophosphate and then the orthophosphate concentrations are measured in accordance with the molybdate protocol outlined by Parsons for orthophosphate concentration determination. The persulfate oxidation reagent is made by dissolving five grams of potassium persulfate in 100 milliliters of deionized distilled water. Reagents were prepared fresh prior to each assay. Each glass tube was filled with 25 milliliters of sample water and then 4 milliliters of persulfate reagent was added. The tubes were tightly capped with aluminum foil and the samples were then autoclaved for 35 minutes at 250^o F and 15 pounds per in^2. After the autoclaving procedure the tubes were allowed to cool and the samples were measured using the Parson's method outlined earlier for

orthophosphate. Once again the only difference for the dissolved phosphorus was the prefiltering step.

Chlorophyll a and phaeophytin concentrations were determined using the method outlined in the JGOFS Protocols, Chapter 14, June 1994. This is a fluorometric technique and a Turner TD-700 Fluorometer using a blue lamp was used to measure raw fluorescence units which were then converted into *u*g chlorophyll a and phaeophytin per liter water utilizing the equation outlined in the JGOFS Protocols. Chlorophyll a standard was purchased from SIGMA. The samples used for the measurements were produced by initially filtering 100 milliliters of water onto a Whatmann GF/F 25-mm glass filter and then placing the filter in a capped, glass tube with eight milliliters of 100% HPLC grade acetone. The filters were allowed to extract in the acetone overnight at - 20°C. Care was always taken to prevent the tubes from receiving excessive light and heat, which would degrade the chlorophyll a into phaeophytin. Phaeophytins are chlorophyll a molecules that have lost their central magnesium atom as a result of degradation. The next day the acetone from each tube was extracted into a clean tube and the fluorescence was measured using the fluorometer.

Cyanobacteria enumeration was conducted using a Zeiss Axioskop Epifluorescence microscope using green light excitiation. Initially samples were collected by filtering 15 milliliters of Lake George water onto a Poretics Products .2 *u*m 25-mm black polycarbonate membrane filter. The filter was then placed onto a clean slide and a single drop of immersion oil was placed on the filter. A cover slip was then placed on the top and all air was carefully removed from

under the cover slip. The slides were then stored at - 20°C until they were enumerated under the microscope using the 100x oil immersion objective. Twenty-five fields per slide were enumerated and an estimate of error is approximately +/- 10 %. After the counting of individual cells and colonies, the number of cells per milliliter was computed using the following formula.

#Cells/ml = (# cells counted/# fields counted)(# fields/filter)(1/volume of sample)

Large colonies were counted by estimating the area using the microscope 10x ocular micrometer and conservatively assuming two cells in depth for the colony.

RESULTS

Physical data and chemical concentration data are provided in tabular and graphic form for all the sampling dates during the summer of 1998. Limited data is also provided for the summer of 1997 (Appendix A). Units of measure are provided with each table. Some nutrient levels were extrapolated below the lowest measured standard in the standard curve using software in the spectrophotometer. The lowest measured standard is provided for each chemical assay and is indicated on the graphs as a heavy bold line.

Secchi disk depth is an approximate measure of water clarity and is widely used in limnological studies because of its simplicity (Wetzel, 1975). In this process a 20-centimeter weighted white and black disk is lowered over the shady side of the boat with a rope or cord marked at one meter intervals until it can no longer be seen. The disk is then raised and the depth at which the disk reappears is recorded as the Secchi disk depth.

The Secchi disk readings for the summer showed that on average the water was clearer at Site Hague in the north basin then at Site Dome in the south. The average Secchi disk depth at Site Hague for the summer 1998 was 10.6 meters and at Site Dome it was 8.8 meters.

Secchi Disk Depth (meters)

Site	5/4/98	5/11/98	5/18/98	5/26/98	6/1/98	6/8/98	6/15/98	6/22/98	6/29/98	7/6/97	7/22/98	8/3/98	8/17/98
Hague	8.5	9	12.5	13.5	11.5	12	9.5	8.5	11.5	10.5	12.5	12.5	8.5
Dome	8	7.5	11	11.5	8	9	9.5	8.5	7	9.5	8.5	8.5	7.5

Table 1

Secchi Dish Depth Profile

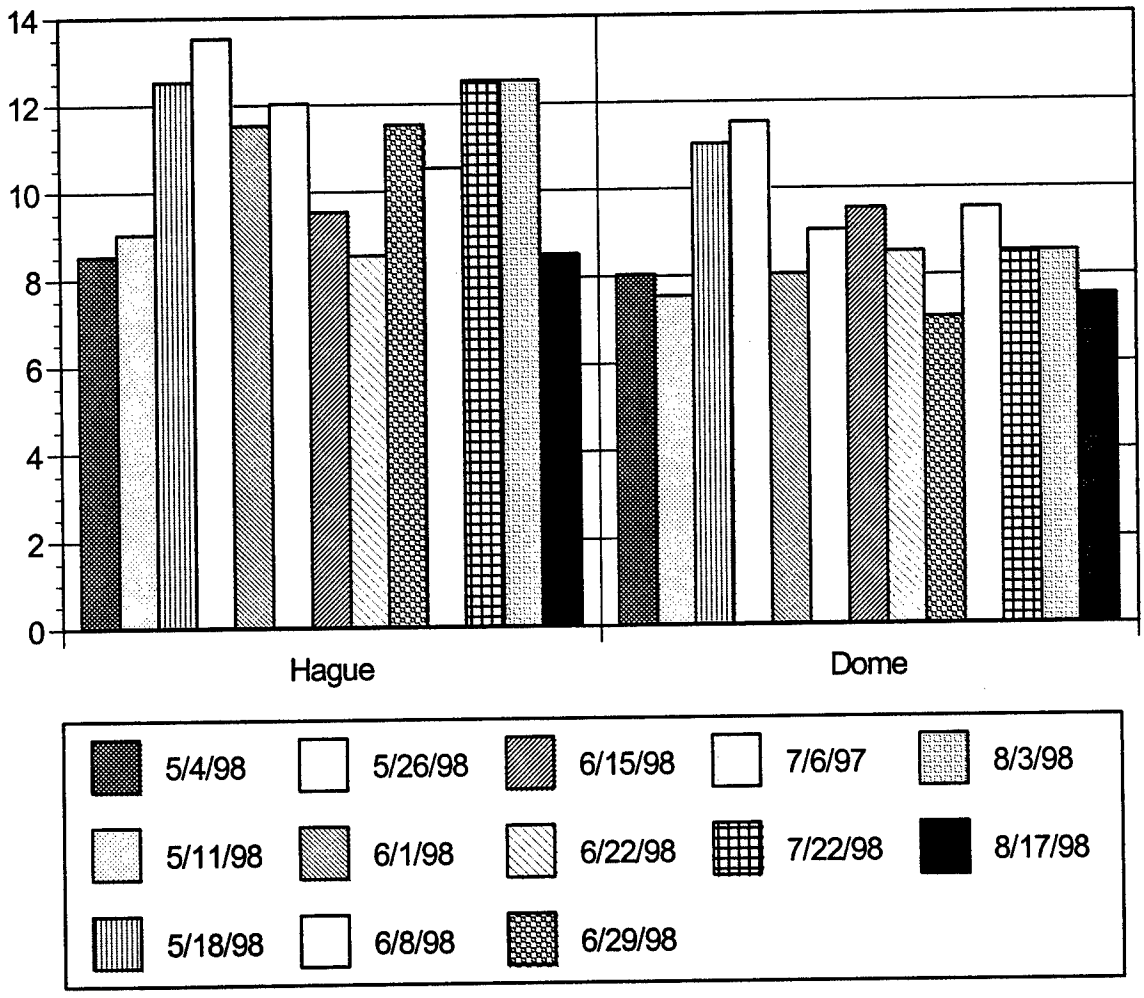

Figure 2

Lake George, like other temperate lakes, stratifies each summer into three distinct layers. A warm surface mixed layer known as the epilimnion, a layer of rapid temperature decrease known as the metalimnion (or thermocline), and a layer of cold water near the bottom known as the hypolimnion. These layers are established progressively during the summer as extended sunlight and wind induced mixing combine to form the stratified layers.

This process had already commenced when this study began and a distinct uniform stratification was established by the end of July with a warm surface layer (epilimnion) extending down to approximately 8 meters at each site. This stratification is also important in that the water is denser and colder in the hypolimnion then in the upper layers of the water column. This factor affects the amount of dissolved gases distributed throughout the water column.

During the peak of stratification, a temperature difference of approximately 19^0 C (from the surface down to 35 meters) was measured in the Lake George water column at each site. Water reached a maximum in the epilimnion near 25^0 C in August at each of the two sites. The coldest water measured (6^0 C) was at a depth of 30 meters and it remained near this temperature throughout the study period at Hague, however a small increase was seen in the temperature at 30 meters at Dome during the study period.

Water Column Temperature Data (°C) – Site Hague

Depth	5/4/98	5/11/98	5/18/98	5/26/98	6/1/98	6/8/98	6/15/98	6/22/98	6/29/98	7/6/97	7/22/98	8/3/98	8/17/98
0	10.2	11.17	14.08	16.06	17.51	16.45	17.79	21.67	21.85	21.92	24.21	23.3	23.58
1	8.48	11.14	13.92	15.76	17.49	16.43	17.78	21.66	21.86	21.92	24.21	23.3	23.58
2	8.33	10.85	13.82	16.6	17.45	16.37	17.76	21.55	21.86	21.89	24.18	23.3	23.58
3	8.3	10.29	13.71	15.59	17.4	16.36	17.72	19.55	21.75	21.88	24.18	23.3	23.58
4	8.2	9.68	13.45	15.26	17.29	16.35	17.68	19.3	21.72	21.87	24.15	23.29	23.58
5	7.98	9.31	13.37	15.19	17.2	16.35	17.67	19.01	21.71	21.85	24.14	23.29	23.58
6	7.77	9.17	13.27	14.94	17.09	16.34	17.66	18.86	20.95	21.84	24.12	23.28	23.58
7	7.67	9.01	12.95	14.41	16.89	16.33	17.62	18.22	18.44	21.61	24.1	23.26	23.57
8	7.48	8.92	12.62	13.41	16.77	16.29	17.39	17.57	15.51	21.32	24.08	23.24	23.57
9	7.3	8.86	12.51	12.15	16.74	16.25	16.87	16.3	13.75	16.7	23.98	23.16	23.56
10	7.12	8.55	12.33	11.8	16.7	16.2	16.54	14.66	13.16	13.4	23.14	22.81	23.54
11	7.01	8.36	11.69	11.06	16.62	16.19	13.54	13.6	12.61	12.97	21.62	19.71	21.85
12	6.9	8.12	11.28	10.64	12.83	15.97	11.57	12.39	11.55	12.05	16.87	14.73	15.03
13	6.86	7.77	10.38	9.82	11.36	12.78	10.47	10.63	10.67	11.42	13.8	12.71	13.87
14	6.76	7.45	8.63	9.2	9.7	10.22	9.34	10.13	10.2	11.12	12.56	12.1	13.06
15	6.62	7.23	8.27	8.84	8.43	9.52	8.85	9.43	9.72	10.46	11.79	11.36	12.28
16	6.59	6.92	7.78	8.52	7.92	8.97	8.65	9.02	9.27	9.79	11.11	11.12	11.63
17	6.48	6.71	7.67	8.03	7.73	8.5	8.52	8.81	8.91	9.51	10.81	10.85	11.33
18	6.41	6.57	7.15	7.78	7.53	8.18	7.92	8.65	8.72	9.16	10.39	10.6	10.93
19	6.26	6.35	7.01	7.45	7.45	7.98	7.64	8.56	8.5	8.68	9.79	10.18	10.44
20	6.21	6.19	6.9	7.19	7.26	7.54	7.54	8.4	8.27	8.31	9.35	9.7	10.16
21	6.13	6.06	6.73	7.07	6.94	7.35	7.42	7.84	7.98	7.91	8.93	9.18	9.35
22	6.08	5.87	6.51	6.93	6.86	7.23	7.27	7.66	7.67	7.61	8.52	8.57	8.95
23	6.06	5.72	6.3	6.66	6.75	7.02	7.07	7.44	7.46	7.17	8.26	8.25	8.54
24	6.04	5.67	6.21	6.51	6.37	6.94	6.92	7.27	7.17	6.87	7.83	7.98	7.68
25	6.01	5.65	6.01	6.41	6.05	6.71	6.3	7.11	6.92	6.35	7.25	7.46	7.29
26	5.99	5.62	5.88	6.35	5.86	6.64	6.11	6.88	6.71	6.2	7.01	7.14	6.93
27	5.97	5.57	5.78	6.24	5.82	6.5	6.07	6.73	6.46	5.83	6.86	6.98	6.85
28	5.89	5.57	5.7	6.09	5.79	6.37	5.86	6.3	6.23	5.78	6.65	6.8	6.54
29	5.61	5.53	5.49	5.67	5.71	6.36	5.84	6.12	6.14	5.74	6.45	6.62	6.44
30	5.58	5.5	5.49	5.63	5.68		5.85	6.11	5.98	5.75	6.39	6.38	6.24

Table 2

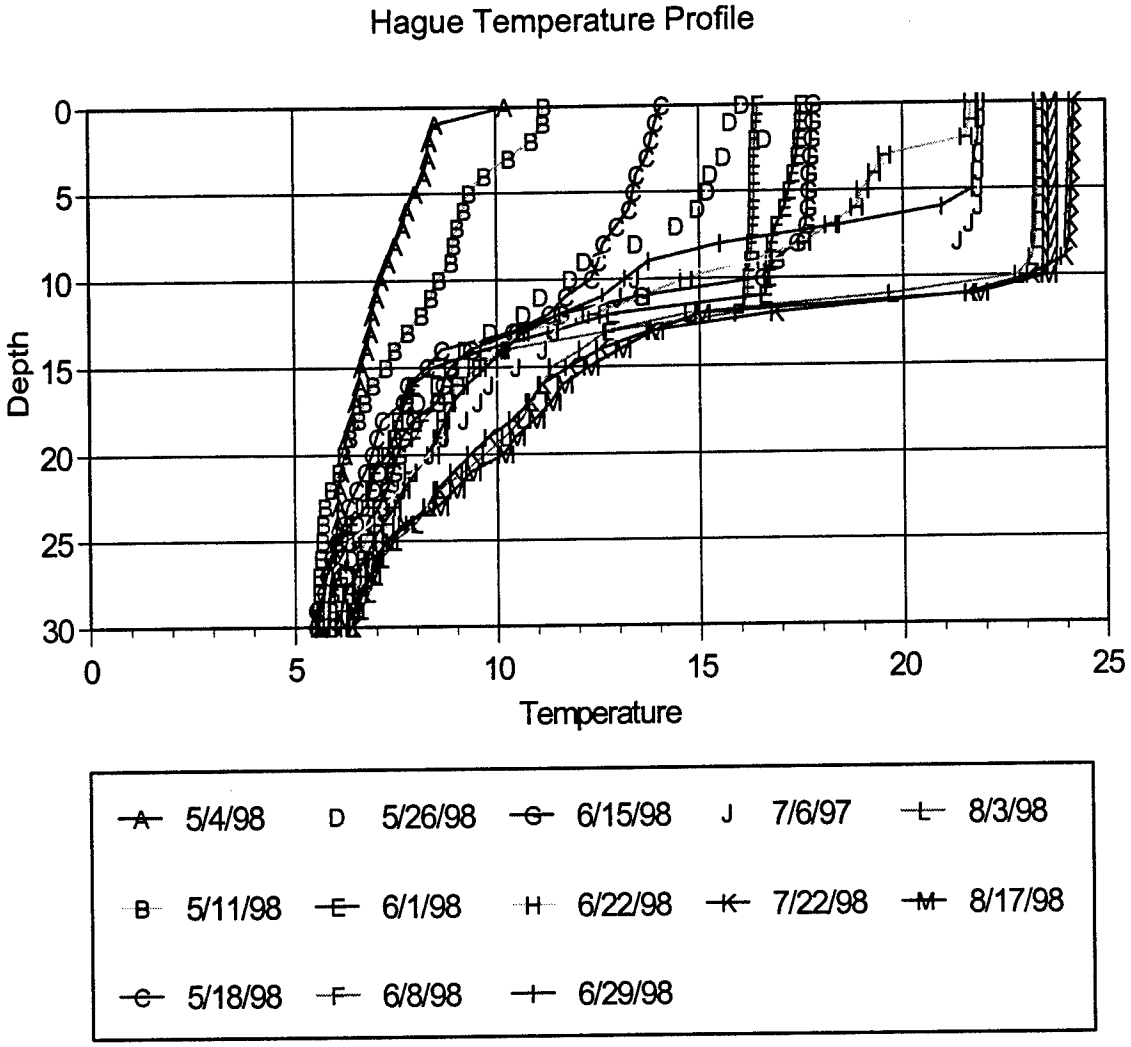
Hague Temperature Profile
Depth
0
5
10
15
20
25
30
0
5
10
15
20
25
Temperature
A 5/4/98
B 5/11/98
C 5/18/98
D 5/26/98
E 6/1/98
F 6/8/98
G 6/15/98
H 6/22/98
I 6/29/98
J 7/6/97
K 7/22/98
L 8/3/98
M 8/17/98

Figure 3

Water Column Temperature Data (°C) – Site Dome

Depth	5/4/98	5/11/98	5/18/98	5/26/98	6/1/98	6/8/98	6/15/98	6/22/98	6/29/98	7/6/97	7/22/98	8/3/98	8/17/98
0	11.3	10.09	16.27	17.1	17.01	15.08	16.44	21.24	21.4	22.24	25.02	24.16	23.04
1	10.56	10.07	15.57	16.57	17.07	15.03	16.42	21.2	21.39	21.98	25.01	23.56	23.04
2	10.4	9.58	15.22	16.34	17	14.91	16.25	21.13	21.39	21.79	24.95	23.4	23.04
3	10.26	9.64	14.76	16.12	17.02	14.87	16.22	20.97	21.34	21.68	24.63	23.29	23.04
4	9.81	8.95	14.12	15.81	16.91	14.84	16.2	20.47	21.32	21.51	24.57	23.12	23.04
5	8.97	8.77	13.78	14.71	16.47	14.82	15.99	20.22	21.06	21.44	24.52	23.08	23.04
6	8.61	8.62	13.12	14.36	16.12	14.8	15.95	20.11	20.96	21.29	24.3	23.02	23.04
7	8.34	8.23	12.35	14	15.8	14.79	15.88	18.5	20.05	21.11	24.05	22.97	23.02
8	7.95	8.09	11.65	13.45	14.88	14.78	15.81	16.89	19.42	20.82	21.27	22.91	23.03
9	7.52	7.89	10.42	13.11	14.14	13.81	15.72	16.51	17.92	18.15	16.67	19.66	22.82
10	7.17	7.73	10.25	12.02	13.97	12.31	15.59	15.7	16.42	15.26	14.41	16.5	21.71
11	7	7.7	9.62	10.05	12.97	11.08	14.47	15.54	15.1	14.8	13.58	14.83	18.43
12	6.85	7.55	9.02	9.43	10.28	10.42	13.22	13.93	14.02	13.89	12.98	13.87	16.44
13	6.8	7.5	8.34	8.94	9.51	9.88	11.73	11.93	13.21	12.49	11.77	13.23	13.59
14	6.72	7.29	8.1	8.66	8.91	9.62	10.79	10.62	12.37	11.21	11.12	12.54	12.95
15	6.52	7.29	7.92	8.41	8.86	9.3	10.42	9.96	11.51	10.81	10.82	11.24	12.03
16	6.29	7.27	7.69	8.37	8.73	9.16	9.62	9.77	10.15	10.51	10.58	10.97	11.87
17	6.14	6.62	7.23	7.88	8.02	9	9.35	9.47	9.9	10.29	10.24	10.76	11.73
18	6.09	6.44	7.14	7.75	7.65	8.72	9.13	9.15	9.43	9.72	9.99	10.68	11.67
19	5.99	6.37	7.13	7.44	7.46	8.66	8.91	8.96	9.11	9.57	9.89	10.6	11.48
20	5.93	6.28	7.12	7.03	7.39	8.57	8.57	8.48	8.96	9.52	9.85	10.46	10.94
21	5.82	6.16	7.1	6.91	7.32	8.43	8.43	8.15	8.72	9.43	9.75	10.18	10.72
22	5.77	6.14	6.88	6.88	7.26	8.31	8.32	8.06	8.61	9.18	9.71	9.76	10.25
23	5.71	6.03	6.72	6.76	6.91	8.27	8.26	8	8.55	9.06	9.63	9.69	9.87
24	5.68	5.91	6.64	6.59	6.9	8.15	8.18	7.91	8.54	9.02	9.47	9.33	9.78
25	5.65	5.84	6.56	6.5	6.84	8.1	8.08	7.88	8.48	8.97	9.17	9.15	9.7
26	5.58	5.78	6.47	6.41	6.82	8.05	8.02	7.86	8.43	8.92		9.02	9.68
27	5.56	5.74	6.32	6.34	6.81	7.92	7.96	7.73	8.16	8.9		8.88	9.6
28	5.52	5.6	6.22	6.25	6.81	7.75	7.86	7.67	7.98	8.89		8.74	9.43
29	5.33	5.41	6.17	6.16	6.8	7.31	7.82		7.98	8.85		8.61	9.35
30		5.35	6.02	6.11	6.75	7.27	7.84		7.86	8.62		8.49	9.25

Table 3

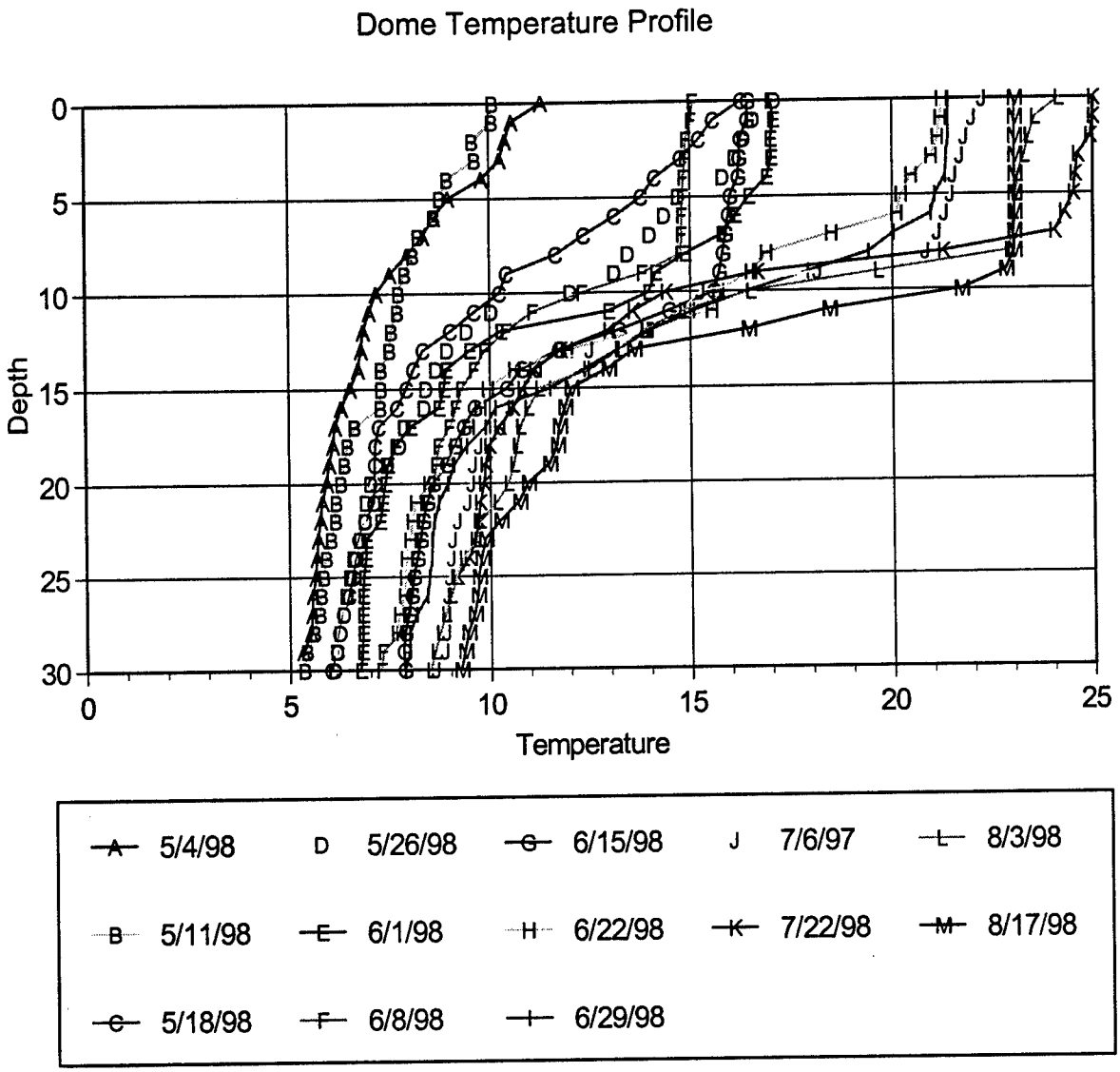
Dome Temperature Profile
Depth
0
5
10
15
20
25
30
0
5
10
15
20
25
Temperature
A 5/4/98
B 5/11/98
C 5/18/98
D 5/26/98
E 6/1/98
F 6/8/98
G 6/15/98
H 6/22/98
I 6/29/98
J 7/6/97
K 7/22/98
L 8/3/98
M 8/17/98

Figure 4

Dissolved oxygen levels within the water column of a dimictic lake are normally uniform throughout the water column during the winter period when the water is covered by ice. As the lake begins to stratify in the late spring the warm water of the epilimnion is unable to retain the previous levels of dissolved oxygen found during the winter. These waters do receive some replacement of oxygen from photosynthesis during the summer, however the warm circulating epilimnetic waters normally are unable to retain excessive dissolved oxygen and remain at equilibrium with the atmosphere during stratification (Wetzel, 1975).

The cold waters of the metalimnion and the hypolimnion remain well saturated during the early part of the summer, but begin to decrease as more organic material settles into these depths and is subsequently oxidatively degraded by bacterial processes. In highly eutrophic lakes (unlike Lake George) this can actually lead to an anoxic layer forming near the sediment where these processes occur at a greater rate.

In some cases a slight increase or decrease in the dissolved oxygen level can occur at the boundary of the metalimnion and the hypolimnion. This is a result of an increase in photosynthetic organisms near this boundary contributing oxygen, but also dying and being decomposed by bacteria.

The Lake George dissolved oxygen profile generally showed a slight decrease during the study period. In some cases there are high readings at the surface and this partly do to increased wave action on the surface as a result of high winds. The cause of the general pattern of decrease in the hypolimnion during the summer was discussed previously. The readings of 17 August appear

excessively low and some doubt to their accuracy is warranted. This could be due to mechanical error with the YSI meter used to take the readings.

Water Column Dissolved Oxygen Data (mgs/L) – Site Hague

Depth	5/4/98	5/11/98	5/18/98	5/26/98	6/1/98	6/8/98	6/15/98	6/22/98	6/29/98	7/6/97	7/22/98	8/3/98	8/17/98
0	11.95	12.14	12.18	9.92	12.36	11.25	11.43	7.96	8.37	6.26	9.9	5.05	2.38
1	12.21	11.97	12.06	10.01	11.26	11.08	11.11	7.87	8.31	6.25	9.93	6.48	3.15
2	12.19	11.99	12.03	10.06	10.79	10.92	10.87	7.79	8.28	6.16	9.93	6.84	3.41
3	12.11	12.14	12.02	10.08	10.66	10.79	10.56	7.84	8.15	6.19	9.91	6.91	3.51
4	12.1	12.26	12.04	10.1	10.62	10.64	10.27	7.76	8.07	6.17	9.87	6.95	3.55
5	12.04	12.29	12.04	10.14	10.66	10.59	10.11	7.7	7.97	6.12	9.83	7.03	3.63
6	12.04	12.28	12.05	10.16	10.71	10.53	9.98	7.67	7.96	6.13	9.78	7.06	3.7
7	12.06	12.28	12.14	10.25	10.8	10.5	9.89	7.6	8.19	6.09	9.73	7.08	3.77
8	12.08	12.27	12.22	10.46	10.92	10.45	9.87	7.56	8.2	6.08	9.69	7.1	3.81
9	12.11	12.25	12.25	10.45	11.19	10.42	9.9	7.6	8.12	6.51	9.66	7.11	3.85
10	12.13	12.3	12.29	10.38	11.33	10.41	9.91	7.72	8.03	6.63	9.81	7.11	3.89
11	12.12	12.32	12.47	10.15	11.57	10.38	10.44	7.81	8.04	6.51	10.47	7.49	4.01
12	12.14	12.4	12.6	10.28	12.14	10.42	10.71	7.95	8.04	6.53	11.21	2.49	2.84
13	12.12	12.44	12.81	10.06	12.21	11.56	10.69	7.92	8.03	6.49	9.29	4.06	3.19
14	12.14	12.46	13.22	9.96	12.2	12.28	10.53	7.84	8.01	6.48	10.02	5.14	3.52
15	12.12	12.46	13.29	9.75	12.19	12.28	10.44	7.79	8.01	6.49	10	5.84	3.76
16	12.1	12.49	13.28	9.7	12.18	12.39	10.35	7.72	7.94	6.5	10.41	6.5	4
17	12.11	12.5	13.21	9.71	12.28	12.41	10.38	7.72	7.9	6.54	10.75	7.03	4.16
18	12.11	12.49	13.24	9.54	12.17	12.34	10.25	7.7	7.86	6.51	10.44	7.3	4.32
19	12.11	12.49	13.11	9.38	12.14	12.3	10.17	7.69	7.86	6.55	10.43	7.66	4.47
20	12.1	12.46	13.05	9.32	12.06	12.23	10.17	7.67	7.85	6.65	10.26	8.06	4.55
21	12.1	12.39	13.07	9.2	12.04	12.16	10.13	7.72	7.89	6.48	10.77	9.1	4.73
22	12.08	12.38	13.03	9.16	12.01	12.05	10.04	7.63	7.79	6.39	10.45	9.04	4.77
23	12.07	12.29	12.97	9.12	11.91	11.94	9.97	7.64	7.76	6.51	10.84	9.32	4.92
24	12.07	12.23	12.88	9.01	11.91	11.85	9.94	7.62	7.74	6.34	10.29	9.61	5.05
25	12.06	12.2	12.85	8.95	11.86	11.79	9.49	7.51	7.65	6.19	9.49	10.67	4.96
26	12.07	12.2	12.69	8.9	11.83	11.7	9.34	7.44	7.6	6.14	9.81	10.63	4.99
27	12.05	12.16	12.58	8.86	11.81	11.6	9.23	7.38	7.44	6.06	9.99	10.62	5.03
28	12.05	12.13	12.47	8.81	11.81	11.32	9.11	7.11	7.34	5.89	9.96	10.51	5.06
29	12.09	12.11	12.45	8.7	11.8	11.24	9.02	7.03	7.27	5.91	9.88	10.48	5.11
30	9.79	10.68	11.9	8.45	11.8		9.25	6.2	7.19	5.92	9.75	10.44	5.31

Table 4

Hague Dissolved Oxygen Profile

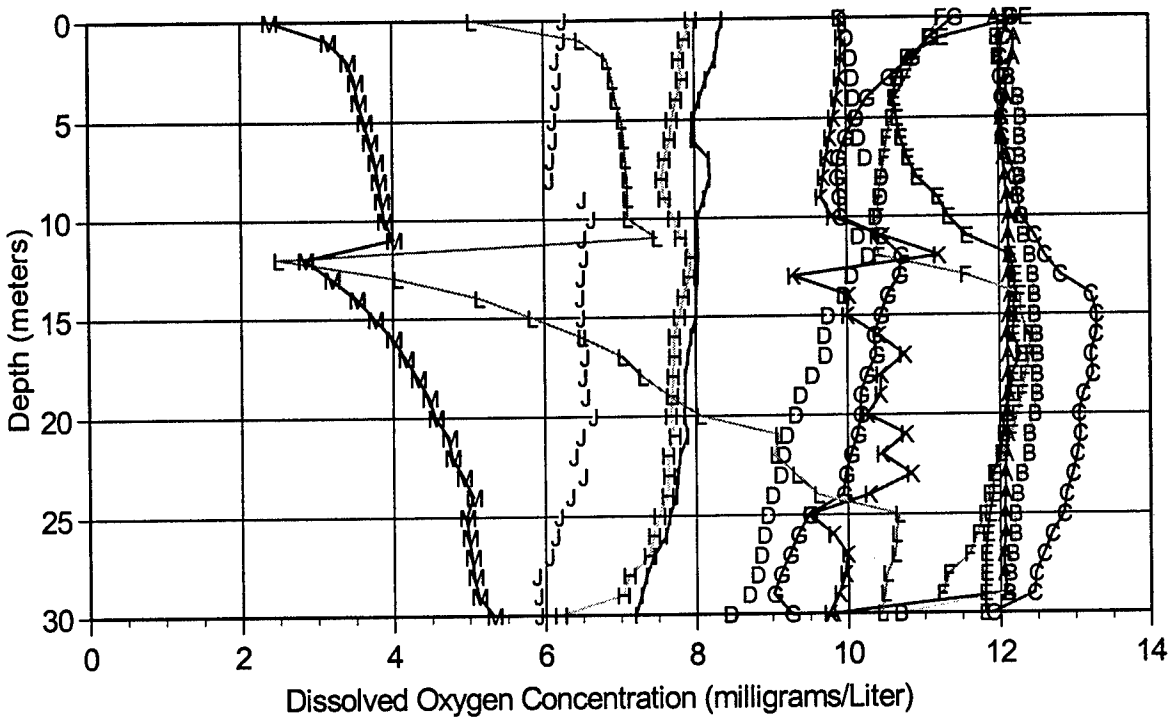

Figure 5

Water Column Dissolved Oxygen Data (mgs/L) – Site Dome

Depth	5/4/98	5/11/98	5/18/98	5/26/98	6/1/98	6/8/98	6/15/98	6/22/98	6/29/98	7/6/97	7/22/98	8/3/98	8/17/98
0	11.89	11.88	11.46	9.53	12.36	12.45	9.29	8.89	7.81	6.15	3.59	12.18	4.36
1	11.97	11.88	11.5	9.79	11.26	11.86	9.22	8.88	7.67	6.15	3.44	10.31	4.41
2	11.98	11.98	11.51	9.52	10.79	11.52	9.15	8.92	7.63	6.13	3.37	9.68	4.43
3	11.97	11.98	11.57	9.71	10.66	11.27	9.1	8.9	7.48	6.13	3.41	9.36	4.43
4	12.05	12.19	11.69	9.68	10.62	11.11	9.04	8.95	7.39	6.1	3.47	9.13	4.43
5	12.21	12.26	11.76	9.59	10.66	10.97	9.03	8.96	7.23	6.15	3.57	8.91	4.43
6	12.28	12.33	11.99	9.81	10.71	10.82	8.96	8.99	7.29	6.1	3.74	8.67	4.42
7	12.32	12.42	12.17	9.51	10.8	10.71	8.98	9.2	7.36	6.13	4.31	8.52	4.4
8	12.37	12.36	12.31	9.6	10.92	10.62	8.95	9.3	7.35	6.17	5.35	8.5	4.36
9	12.41	12.29	12.66	9.64	11.19	10.74	8.95	9.23	7.36	6.16	6.13	8.44	4.29
10	12.4	12.3	12.69	9.61	11.33	11.05	8.96	9.23	7.32	6.24	7.63	8.44	4.19
11	12.4	12.32	12.83	9.31	11.57	11.33	9.12	9.21	7.3	6.45	8.86	8.23	3.83
12	12.37	12.35	12.91	8.98	12.14	11.38	9.33	9.32	7.26	6.56	9.85	8.07	3.52
13	12.31	12.35	12.99	8.98	12.21	11.48	9.47	9.39	7.24	6.52	9.8	7.85	3.56
14	12.28	12.39	12.99	9.05	12.2	11.48	9.59	9.36	7.24	6.67	9.61	7.92	3.36
15	12.24	12.33	12.96	9.05	12.19	11.47	9.63	9.43	7.27	6.72	8.76	7.99	3.34
16	12.24	12.34	12.95	9.02	12.18	11.42	9.72	9.43	7.2	6.68	8.16	7.56	3.32
17	12.16	12.45	12.99	9.02	12.28	11.39	9.66	9.5	7.23	6.76	8.11	7.22	3.32
18	12.13	12.37	12.91	8.88	12.17	11.38	9.63	9.46	7.18	6.7	8.03	7.02	3.3
19	12.11	12.36	12.8	8.85	12.14	11.25	9.52	9.46	7.14	6.76	8.05	7.03	3.33
20	12.09	12.34	12.77	8.73	12.06	11.29	9.46	9.37	7.15	6.76	7.92	7.05	3.34
21	12.07	12.31	12.75	8.58	12.04	11.23	9.35	9.34	7.13	6.77	7.75	7.1	3.31
22	12.04	12.26	12.8	8.49	12.01	11.23	9.3	9.3	7.11	6.71	7.62	7.06	3.32
23	12.02	12.3	12.77	8.51	11.91	11.18	9.31	9.29	7.12	6.77	7.61	6.9	3.14
24	12	12.22	12.73	8.52	11.91	11.18	9.31	9.41	7.12	6.72	7.14	6.78	3.07
25	11.99	12.21	12.72	8.39	11.86	11.12	9.31	9.35	7.08	6.76	6.49	6.65	3.06
26	11.98	12.22	12.7	8.36	11.83	11.05	9.35	9.37	7.11	6.68		6.52	3.03
27	11.95	12.2	12.7	8.34	11.81	11.06	9.33	9.34	7.12	6.77		6.4	3
28	11.94	12.21	12.66	8.33	11.81	11.05	9.35	9.4	7.09	6.68		6.32	3
29	11.97	12.19	12.63	8.27	11.8	11.02	9.34		7.07	6.69		6.3	2.98
30		12.16	12.59	8.21	11.8	10.97	9.32		7.13	6.71		6.26	2.98

Table 5

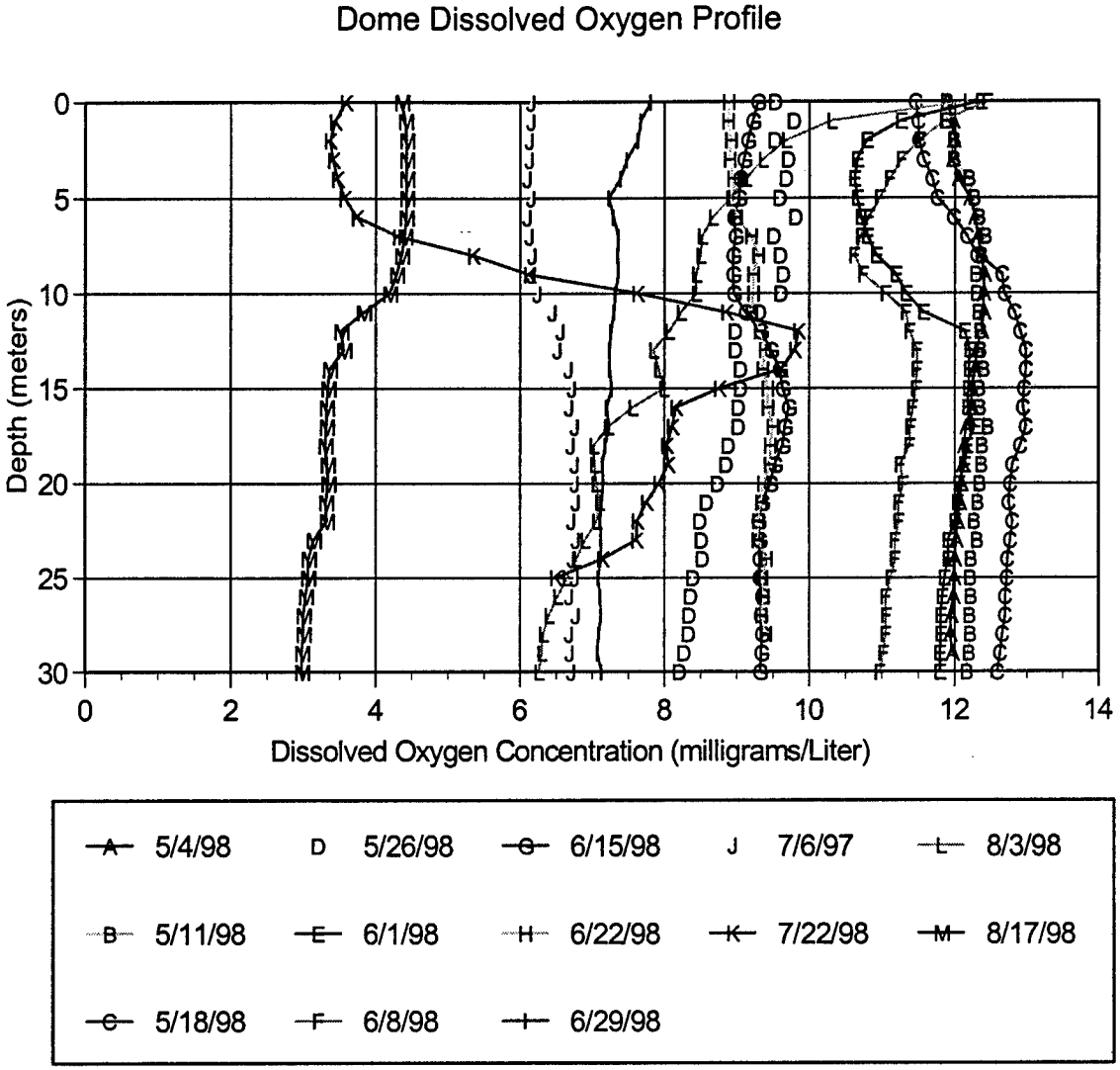
Dome Dissolved Oxygen Profile
Depth (meters)
0
5
10
15
20
25
30
0
2
4
6
8
10
12
14
Dissolved Oxygen Concentration (milligrams/Liter)
A 5/4/98
B 5/11/98
C 5/18/98
D 5/26/98
E 6/1/98
F 6/8/98
G 6/15/98
H 6/22/98
I 6/29/98
J 7/6/97
K 7/22/98
L 8/3/98
M 8/17/98

Figure 6

Specific conductance is the measure of the resistance of a solution to electrical flow. This is a measure of the salinity of water, hence the amount of salts in a water column. These are primarily in the form of several different cations, such as calcium, magnesium, sodium and potassium, and anions, such as carbonate, sulfate, and chloride. These cations and anions enter the water column from atmospheric deposition and through biogeochemical processes from the Lake George watershed.

The greater the concentration of these salts, the higher the specific conductance measurement. Temperature affects these readings and specific conductance increases about 2 % per degree Celsius (Wetzel, 1975).

The specific conductance levels in Lake George show higher salinity levels in the epilimnion throughout the entire study period at both Site Hague and Site Dome. These higher readings are probably do to the increased temperature of the water and atmospheric deposition and surface runoff. There was also a general increase in specific conductance during the summer at both sites. The specific conductance measurements ranged from highs near 125 at the surface of both sites at the end of the study period to the 70s and 80s near 30 meters in depth during the entire summer.

Water Column Specific Conductance Data (micromhos/cm) – Site Hague

Depth	5/4/98	5/11/98	5/18/98	5/26/98	6/1/98	6/8/98	6/15/98	6/22/98	6/29/98	7/6/97	7/22/98	8/3/98	8/17/98
0	88	89	98	111	107	105	105	114	114	114	120	118	120
1	83	89	98	112	108	105	103	115	114	115	119	118	120
2	83	89	98	112	108	105	106	113	114	114	119	118	120
3	83	86	96	112	110	103	106	109	116	115	119	118	120
4	82	88	96	112	106	106	103	109	114	112	119	118	120
5	82	89	96	115	107	101	103	108	113	121	119	118	119
6	81	85	95	116	108	103	104	102	108	112	119	118	119
7	83	81	95	112	111	97	103	110	108	110	118	118	119
8	80	89	95	110	106	111	109	111	89	113	118	118	119
9	80	85	94	112	105	102	104	98	98	96	118	118	119
10	79	83	94	115	105	103	100	106	85	97	116	117	119
11	81	81	94	115	108	101	101	93	98	107	113	109	115
12	79	82	93	117	94	105	90	95	98	91	102	96	98
13	79	86	90	112	91	102	81	93	81	94	94	91	95
14	80	82	87	115	91	96	77	91	83	89	93	90	93
15	76	79	84	116	89	88	82	80	102	84	91	88	91
16	76	81	80	120	86	83	86	84	85	83	90	88	90
17	77	78	83	120	80	81	86	80	82	78	89	85	89
18	74	76	81	115	86	80	80	87	91	80	88	87	88
19	82	80	86	115	92	81	68	85	81	77	87	86	87
20	76	85	81	115	82	80	75	81	80	79	86	85	86
21	77	85	81	117	85	81	73	78	76	80	85	84	85
22	72	71	74	118	97	81	83	80	78	74	84	82	84
23	80	81	84	120	77	78	87	74	86	87	83	82	83
24	76	81	80	115	77	78	72	69	87	79	82	81	81
25	78	87	81	120	76	82	79	70	82	68	81	78	80
26	83	82	81	125	85	78	72	76	83	80	81	79	80
27	76	83	80	125	72	89	78	91	70	79	80	79	79
28	79	72	82	120	89	71	74	90	70	77	80	79	79
29	74	74	74	115	71	81	75	85	79	71	79	79	78
30	75	86	74	120	83		82	89	80	85	79	78	78

Table 6

Hague Specific Conductance Profile

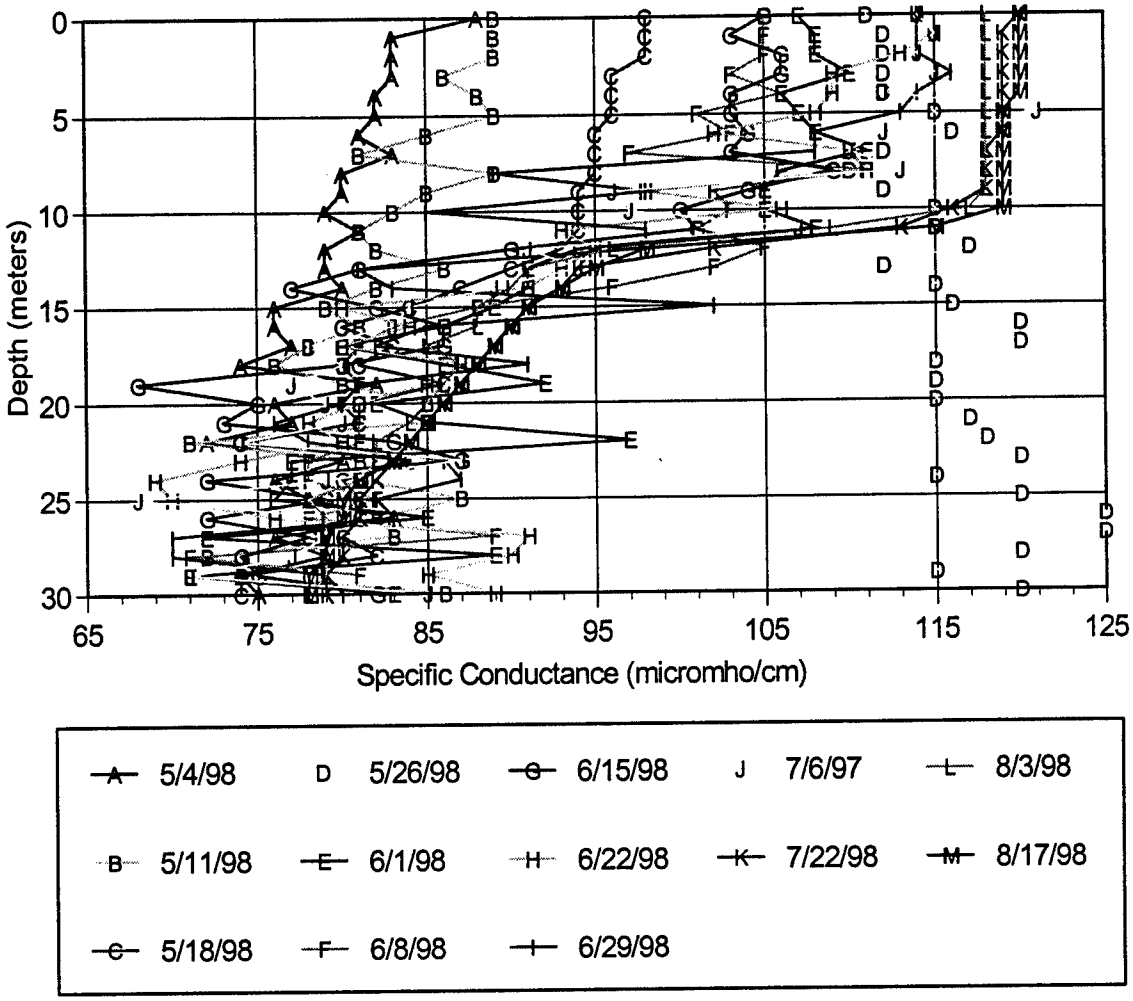

Figure 7

Water Column Specific Conductance Data (micromhos/cm) – Site Dome

Depth	5/4/98	5/11/98	5/18/98	5/26/98	6/1/98	6/8/98	6/15/98	6/22/98	6/29/98	7/6/97	7/22/98	8/3/98	8/17/98
0	91	87	106	113	107	102	102	113	111	114	125	121	118
1	88	88	106	112	108	102	103	112	111	114	125	120	118
2	87	87	104	113	108	101	102	112	114	116	124	119	118
3	88	87	102	114	110	101	101	115	112	114	123	119	118
4	86	87	101	110	106	100	99	109	113	111	122	118	118
5	85	84	99	110	107	106	98	113	110	116	122	118	118
6	82	84	97	115	106	102	100	115	110	107	122	118	118
7	84	82	89	112	102	106	100	109	111	110	121	118	118
8	85	85	90	114	101	107	97	104	107	112	112	117	118
9	78	82	93	116	102	96	101	103	107	113	102	109	117
10	82	85	87	113	103	97	100	100	97	98	96	101	113
11	80	83	87	109	100	91	96	101	98	100	94	96	106
12	82	83	90	117	94	94	99	104	109	94	93	94	102
13	77	79	86	110	79	86	95	103	80	87	90	92	95
14	78	79	84	112	81	84	89	89	97	97	89	91	92
15	81	81	88	113	74	72	96	91	102	94	87	88	90
16	78	79	85	118	84	88	89	89	91	89	87	87	90
17	80	80	83	115	87	97	88	78	87	79	86	87	89
18	81	84	83	112	90	91	88	81	76	75	85	87	89
19	79	83	87	117	77	82	84	68	97	88	85	86	89
20	77	84	81	116	82	98	86	74	75	75	85	86	88
21	81	81	78	113	87	82	92	95	89	99	85	87	87
22	89	81	82	115	86	83	87	75	81	82	85	85	86
23	83	85	81	108	89	75	72	70	87	93	85	84	85
24	77	81	82	112	86	79	86	77	95	88	84	84	85
25	81	78	85	112	72	82	81	78	82	82	85	83	85
26	79	81	88	116	80	86	84	73	96	99		82	85
27	88	78	83	115	90	83	85	79	82	95		82	85
28	83	78	87	116	90	84	82	79	69	94		82	84
29	75	76	71	113	88	81	88		86	89		81	84
30		78	74	110	88	81	82		86	87		82	84

Table 7

Dome Specific Conductance Profile

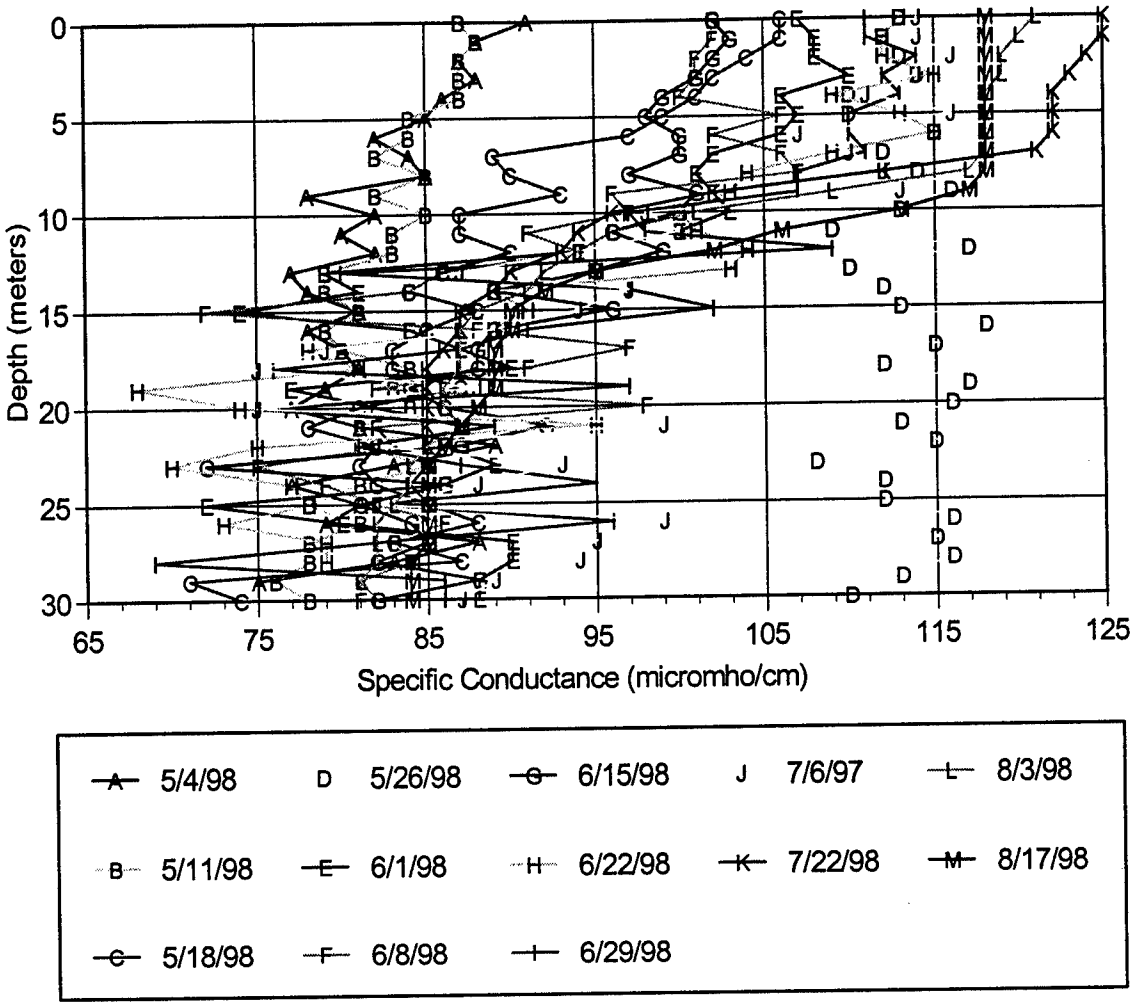

Figure 8

pH is the measure of H^+ concentration in the water column and the actual reported data is the negative log of the H^+ concentration. In most temperate lakes pH is the result of the dissociation of H_2CO_3 to HCO_3^- and CO_3^{2-} with the release of H^+. (Wetzel, 1975)

Lake George pH levels fall within the range outlined by Wetzel for most open lakes (pH 6 to 9). The data at both sites show similar patterns in pH readings. The pH tends to be slightly higher at the surface and declining with depth. At both sites there appears to be some difference that begins on the 22 July sampling date and continues until the end of the sampling period. This difference is a drop in pH at or just below the metalimnion followed by an increase.

Water Column pH Data (Log [H+]) – Site Hague

Depth	5/4/98	5/11/98	5/18/98	5/26/98	6/1/98	6/8/98	6/15/98	6/22/98	6/29/98	7/6/97	7/22/98	8/3/98	8/17/98
0	7.85	7.78	7.83	8	7.97	8.07	8.07	7.97	8.06	8.02	7.03	7.3	7.43
1	7.87	7.81	7.83	7.97	7.97	8.07	8.07	7.98	8.06	8.01	7.05	7.36	7.49
2	7.87	7.84	7.83	7.93	7.98	8.06	8.04	7.98	8.05	8.02	7.06	7.39	7.51
3	7.87	7.8	7.82	7.91	7.97	8.05	8.01	8.14	8.05	8.02	7.06	7.41	7.52
4	7.87	7.79	7.82	7.89	7.97	8.04	7.98	8.17	8.04	8.01	7.07	7.43	7.53
5	7.87	7.84	7.8	7.87	7.96	8.02	7.98	8.18	8	7.98	7.08	7.43	7.54
6	7.85	7.81	7.82	7.85	7.96	8.02	7.95	8.13	7.96	7.98	7.08	7.44	7.53
7	7.85	7.84	7.81	7.84	7.96	8.04	7.98	8.12	8	7.96	7.09	7.45	7.54
8	7.86	7.83	7.81	7.84	7.95	8.02	8.01	8.09	7.92	7.92	7.09	7.45	7.54
9	7.86	7.79	7.83	7.83	7.95	8.05	8	8.01	7.82	7.95	7.09	7.46	7.54
10	7.86	7.84	7.81	7.81	7.98	8.02	7.96	7.96	7.78	7.88	7.09	7.44	7.53
11	7.85	7.85	7.84	7.81	7.94	8.02	7.87	7.9	7.76	7.8	7.07	7.38	7.5
12	7.84	7.84	7.84	7.8	8.08	8.01	7.89	7.88	7.78	7.72	6.96	7.33	7.44
13	7.83	7.82	7.89	7.8	8.07	8.01	7.85	7.83	7.73	7.71	6.78	7.23	7.38
14	7.83	7.81	7.9	7.8	8.18	7.98	7.78	7.69	7.73	7.66	6.66	7.16	7.33
15	7.81	7.79	7.97	7.78	8.05	7.97	7.72	7.65	7.73	7.64	6.57	7.14	7.25
16	7.83	7.8	7.88	7.77	8	7.95	7.69	7.64	7.67	7.63	6.52	6.74	6.6
17	7.82	7.78	7.8	7.74	7.91	7.98	7.7	7.63	7.66	7.62	6.49	6.86	6.96
18	7.83	7.73	7.78	7.71	7.86	7.91	7.72	7.63	7.67	7.65	6.47	6.81	6.91
19	7.8	7.73	7.73	7.66	7.85	7.89	7.69	7.65	7.66	7.65	6.21	6.91	6.99
20	7.71	7.72	7.72	7.64	7.83	7.86	7.71	7.67	7.67	7.65	5.79	6.97	7.03
21	7.8	7.71	7.75	7.62	7.78	7.8	7.67	7.69	7.66	7.63	6.13	7.01	7.03
22	7.75	7.65	7.73	7.58	7.75	7.73	7.66	7.67	7.64	7.58	6.22	7.01	7.04
23	7.76	7.66	7.7	7.54	7.73	7.73	7.64	7.66	7.61	7.57	6.28	7.01	7.04
24	7.75	7.62	7.67	7.51	7.66	7.72	7.59	7.64	7.58	7.53	6.3	7.01	7
25	7.76	7.63	7.65	7.49	7.59	7.69	7.5	7.62	7.52	7.5	6.3	7	6.97
26	7.76	7.63	7.62	7.47	7.51	7.66	7.42	7.56	7.5	7.46	6.31	6.98	6.97
27	7.75	7.61	7.59	7.45	7.51	7.64	7.4	7.53	7.46	7.36	6.34	6.97	6.98
28	7.75	7.59	7.55	7.42	7.48	7.59	7.38	7.44	7.42	7.31	6.34	6.97	6.95
29	7.72	7.59	7.56	7.36	7.48	7.42	7.37	7.04	7.38	7.28	6.34	6.97	6.96
30	7.56	7.29	7.23	7.23	7.44		6.96	7.15	7.37	7.05	6.33	6.96	6.93

Table 8

Hague Water Column pH Profile

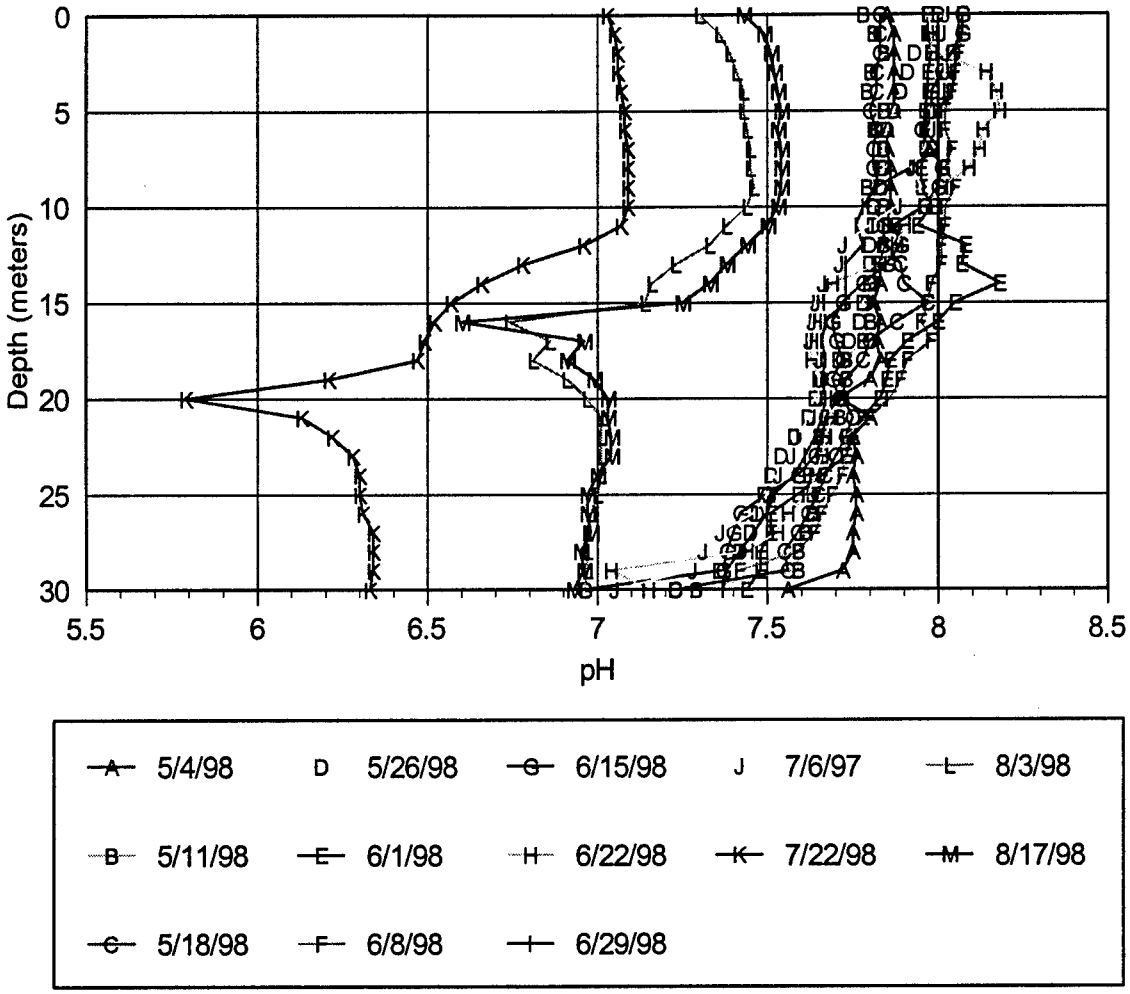

Figure 9

Water Column pH Data (Log [H+]) – Site Dome

Depth	5/4/98	5/11/98	5/18/98	5/26/98	6/1/98	6/8/98	6/15/98	6/22/98	6/29/98	7/6/97	7/22/98	8/3/98	8/17/98
0	7.87	7.9	7.78	7.46	7.92	7.98	7.91	7.82	7.86	7.81	7.11	7.16	7.24
1	7.89	7.89	7.79	7.46	7.92	8	7.92	7.84	7.84	7.79	7.13	7.19	7.28
2	7.9	7.89	7.79	7.47	7.96	8.02	7.92	7.85	7.87	7.81	7.14	7.21	7.3
3	7.89	7.9	7.8	7.48	7.95	8.01	7.9	7.84	7.87	7.8	7.15	7.25	7.32
4	7.85	7.92	7.83	7.47	7.95	8.02	7.91	7.86	7.86	7.82	7.16	7.28	7.33
5	7.91	7.92	7.84	7.51	7.95	8.02	7.94	7.85	7.89	7.82	7.17	7.27	7.35
6	7.92	7.92	7.85	7.53	7.94	8.01	7.95	7.89	7.9	7.82	7.18	7.27	7.36
7	7.92	7.88	7.84	7.53	7.9	7.98	7.94	8.02	7.92	7.85	7.2	7.28	7.36
8	7.92	7.84	7.87	7.52	7.88	7.98	7.94	8.1	7.98	7.89	7.21	7.28	7.37
9	7.91	7.81	7.89	7.52	7.86	7.96	7.91	8.07	7.98	7.76	7.04	7.29	7.37
10	7.88	7.83	7.89	7.52	7.88	7.89	7.91	7.96	7.89	7.66	6.87	7.18	7.32
11	7.86	7.81	7.89	7.49	7.89	7.8	7.88	7.9	7.81	7.67	6.74	7.12	7.18
12	7.84	7.8	7.86	7.46	7.73	7.72	7.81	7.73	7.67	7.62	6.31	6.87	7.03
13	7.83	7.8	7.8	7.44	7.67	7.65	7.7	7.57	7.62	7.52	6.34	6.8	6.94
14	7.82	7.77	7.79	7.42	7.66	7.62	7.63	7.5	7.56	7.42	6.24	6.79	6.63
15	7.8	7.81	7.78	7.39	7.67	7.6	7.61	7.46	7.53	7.4	6.32	6.7	6.68
16	7.76	7.79	7.79	7.37	7.66	7.57	7.55	7.46	7.42	7.39	6.32	6.62	6.72
17	7.73	7.7	7.73	7.33	7.61	7.56	7.48	7.47	7.42	7.37	6.32	6.65	6.74
18	7.72	7.67	7.72	7.31	7.57	7.55	7.45	7.42	7.42	7.36	6.34	6.66	6.76
19	7.7	7.65	7.7	7.28	7.55	7.52	7.42	7.41	7.37	7.33	6.35	6.67	6.78
20	7.7	7.63	7.69	7.23	7.53	7.53	7.38	7.38	7.38	7.3	6.37	6.7	6.77
21	7.67	7.6	7.67	7.21	7.53	7.48	7.35	7.34	7.35	7.31	6.38	6.71	6.77
22	7.67	7.6	7.65	7.19	7.53	7.48	7.35	7.32	7.33	7.32	6.39	6.74	6.77
23	7.66	7.59	7.63	7.18	7.48	7.48	7.34	7.32	7.32	7.31	6.39	6.74	6.76
24	7.65	7.57	7.61	7.16	7.48	7.46	7.35	7.31	7.31	7.29	6.39	6.73	6.77
25	7.66	7.57	7.63	7.14	7.48	7.47	7.36	7.3	7.33	7.29	6.12	6.74	6.76
26	7.64	7.55	7.62	7.12	7.46	7.45	7.35	7.3	7.3	7.29		6.73	6.77
27	7.64	7.54	7.59	7.11	7.47	7.46	7.35	7.29	7.31	7.26		6.73	6.78
28	7.62	7.53	7.59	7.1	7.46	7.44	7.33	7.29	7.32	7.27		6.75	6.78
29	7.61	7.52	7.56	7.09	7.44	7.42	7.33		7.3	7.27		6.77	6.78
30		7.42	7.55	7.07	7.45	7.42	7.34		7.29	7.29		6.79	6.8

Table 9

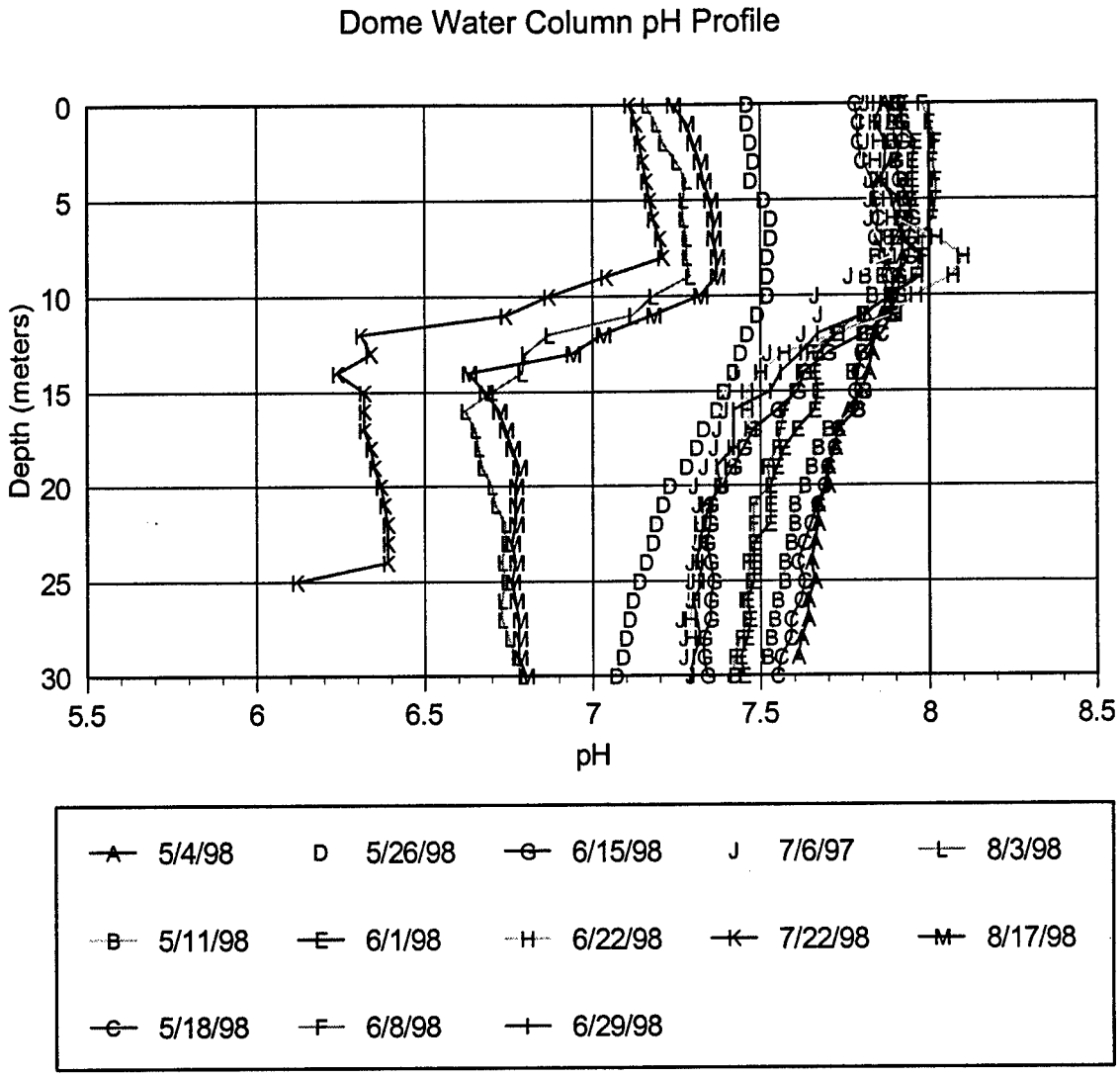
Dome Water Column pH Profile
Depth (meters)
0
5
10
15
20
25
30
5.5
6
6.5
7
7.5
8
8.5
pH
A 5/4/98
B 5/11/98
C 5/18/98
D 5/26/98
E 6/1/98
F 6/8/98
G 6/15/98
H 6/22/98
I 6/29/98
J 7/6/97
K 7/22/98
L 8/3/98
M 8/17/98

Figure 10

Light is important to many aspects of the water column. Selective absorption of red and infrared wavelengths are responsible for major warming of the epilimnion and scattering of blue and green wavelengths by water molecules, particulate matter and living organisms gives water its distinctive color (Wetzel, 1975). Light is also utilized for photosynthesis by plants and phytoplankton in the lake.

Percent illumination is a measure of how much surface irradiance is reaching a particular depth in the water column. Light decreases exponentially with depth of the water column. In Lake George the illumination dropped to approximately 10 % in the first 8 to 10 meters of water. Measurable light levels were found as low as it was possible to measure with the equipment available (28 meters) and as discussed later in this paper, minimal light levels at 25 meters were still adequate to allow photosynthesis by picophytoplankton.

Water Column Percent Illumination Data – Site Hague

Depth	5/4/98	5/11/98	5/18/98	5/26/98	6/1/98	6/8/98	6/15/98	6/22/98	6/29/98	7/6/97	7/22/98	8/3/98	8/17/98
0	70	65	80	69	69	68	56	61	59	77	98	85	55.4
1	56	55	66	52	44	55	45	45	42	68	79	76	40.5
2	31	39	57	40	32	44	33	33	29	41	51	52.3	32.3
3	26	29.8	45	35	26	36	24	25	24.5	34	54	35.6	26.3
4	25	23.7	32	27	24	31	22	22	20.5	23	39	25.7	21.2
5	22	19.9	23	23	20	24	19	19.6	17.2	20	29	22.1	18.4
6	15	15.9	20	20	19	21	16.7	16.2	14.7	16	23	18.1	15.5
7	13	13.4	16	17	15	17	14.5	12.3	12.4	13.7	20	14.3	13.2
8	10.5	10.9	13	14	14	13.7	12.5	9.9	10.1	10.7	17	11.2	10.9
9	8.7	8.7	11	12	11	11.7	10.5	8.3	7.8	8.4	12.4	8.6	8.5
10	6.8	6.9	8	10	9	9.5	8	6.7	6.45	6.4	9.1	6.6	7.3
11	5.6	5.6	7.5	8.1	8	7.9	5.3	5.2	5.13	4.8	7.7	6	5.9
12	4.9	4.6	5.8	6.8	7	6.7	4.2	4.4	4.26	4.3	6.4	4.8	4.6
13	3.9	3.9	5	5.9	6	5.4	3.4	3.5	3.46	3	5.6	3.9	3.7
14	3.2	3.2	4	4.9	4.4	4.4	2.8	2.9	2.83	2.4	4.3	3.1	2.8
15	2.9	2.5	3.3	4	4.1	3.7	2.4	2.4	2.27	2.1	3.6	2.4	2.3
16	2.3	2.2	2.9	3.3	3.5	3	2	1.9	1.9	1.7	2.7	1.9	1.7
17	2	1.9	2.2	2.7	4	2.6	1.5	1.6	1.57	1.4	2.2	1.6	1.4
18	1.6	1.5	1.9	2.3	2.3	2.1	1.3	1.3	1.32	1.2	1.8	1.3	1.1
19	1.5	1.3	1.5	1.9	2	1.8	1.1	1.1	1.08	0.89	1.6	1	0.91
20	1.3	1.1	1.3	1.6	1.6	1.5	0.98	0.93	0.91	0.79	1.2	0.83	0.75
21	0.96	0.93	1.1	1.3	1.4	1.2	0.8	0.75	0.76	0.62	1	0.72	0.6
22	0.9	0.76	0.9	1.1	1.4	1	0.68	0.63	0.62	0.55	0.89	0.59	0.51
23	0.7	0.65	0.8	0.95	0.9	0.8	0.55	0.51	0.52	0.46	0.71	0.49	0.43
24	0.6	0.54	0.67	0.81	0.8	0.7	0.45	0.42	0.44	0.38	0.58	0.41	0.41
25	0.5	0.43	0.57	0.68	0.7	0.6	0.38	0.35	0.37	0.32	0.49	0.35	0.35
26	0.43	0.38	0.45	0.57	0.53	0.5	0.36	0.29	0.31	0.28	0.43	0.29	0.31
27	0.37	0.32	0.38	0.49	0.49	0.42	0.27	0.25	0.26	0.24	0.35	0.24	0.25
28	0.3	0.26	0.31	0.41	0.42		0.22	0.2	0.22	0.19	0.31	0.2	0.22

Table 10

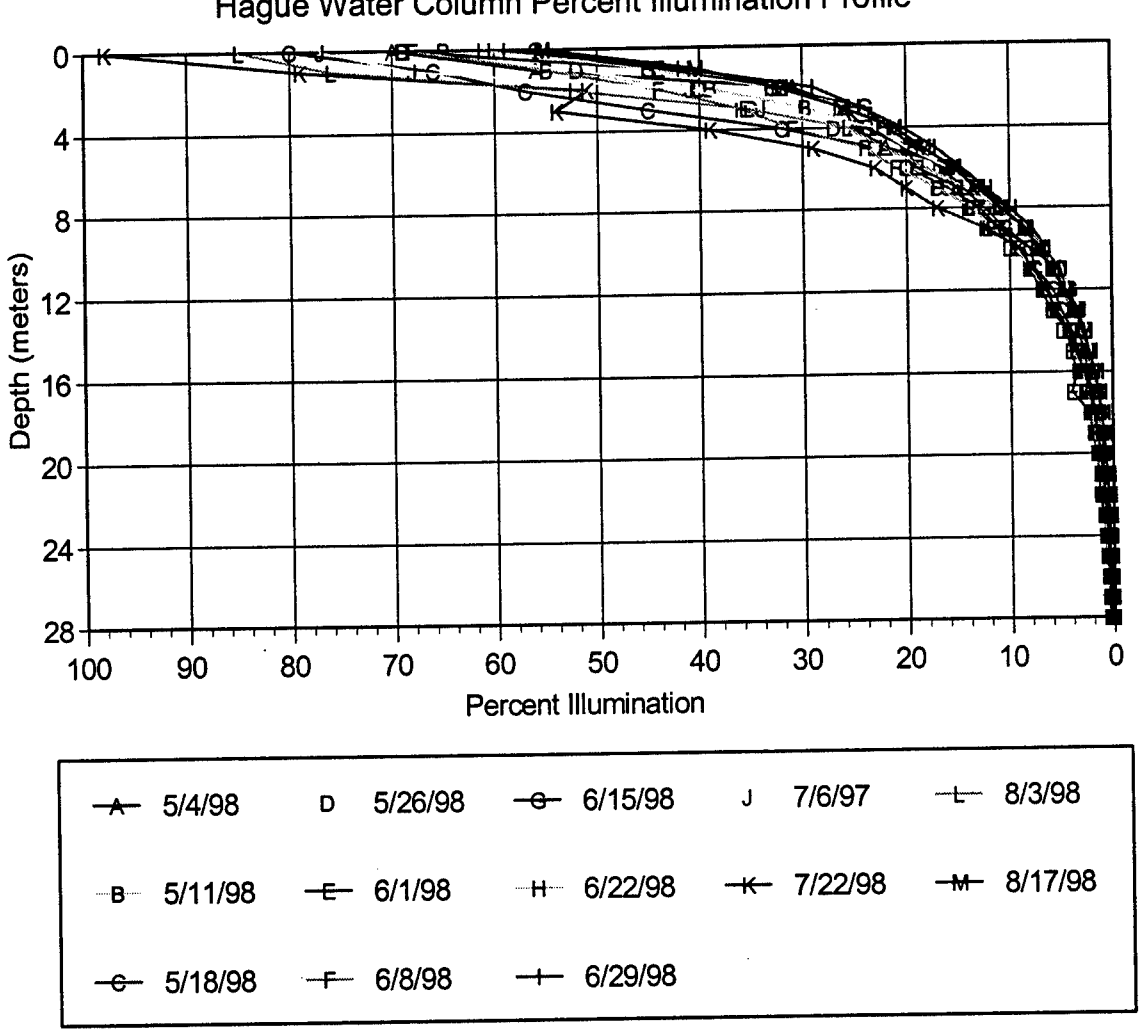
Hague Water Column Percent Illumination Profile
Depth (meters)
0
4
8
12
16
20
24
28
100
90
80
70
60
50
40
30
20
10
0
Percent Illumination
A 5/4/98
B 5/11/98
C 5/18/98
D 5/26/98
E 6/1/98
F 6/8/98
G 6/15/98
H 6/22/98
I 6/29/98
J 7/6/97
K 7/22/98
L 8/3/98
M 8/17/98

Figure 11

Water Column Percent Illumination Data – Site Dome

Depth	5/4/98	5/11/98	5/18/98	5/26/98	6/1/98	6/8/98	6/15/98	6/22/98	6/29/98	7/6/97	7/22/98	8/3/98	8/17/98
0	56	65	85	78	65	48	67	71	48.7	67	89	75.4	40
1	41.1	55	71	58	44	40	58	56	35.9	64	74	59.8	34.7
2	30.3	41	56	45	29	33	42	43	29.5	41	68	40.1	24.4
3	26.7	27	39	33	22	27	31	33	26.4	32	47	33.5	19.9
4	20.8	22	28	29	18	22	27	25	19.9	22	30	25.7	16.8
5	17.3	16	23	21	17	17	21	19	17.1	16	25	19.8	14.1
6	13.5	13	19	17	14	14	18	15	13	14.5	21	16	11.9
7	11.1	11	16	14	12	11	14	12.7	10.9	11.2	16	12.8	9.6
8	8.6	8	13	11	10	9.5	9.7	9	8.2	8.5	12.6	10.7	7.6
9	6.8	6.4	10	8.7	8	7.8	7.9	8.3	6	6.6	8.9	7.7	5.8
10	5.37	4.9	6.6	7.3	6.6	6	6.4	6.5	4.9	4.8	7	5.9	4.2
11	4.03	4	5.3	5.6	5.9	4.8	5.1	4.8	3.7	4.2	5.4	4.9	3.2
12	3.13	3	4.3	4.4	4.6	3.8	4	3.8	3	3.4	4.3	3.3	2.4
13	2.43	2.4	3.4	3.6	3.6	3	3.1	3	2.3	2.1	3.4	2.4	1.7
14	1.92	2.1	2.7	3.1	3	2.4	2.5	2.5	1.9	1.8	2.6	1.9	1.4
15	1.51	1.6	2.2	2.4	2.3	2	2	2	1.5	1.4	1.9	1.5	1
16	1.2	1.2	1.8	1.9	1.8	1.6	1.6	1.6	1.2	1.2	1.7	1.2	0.84
17	0.95	1	1.5	1.5	1.6	1.3	1.3	1.4	0.96	0.9	1.4	1	0.64
18	0.77	0.82	1.1	1.2	1.4	1.1	1.1	1	0.76	0.81	1.1	0.77	0.49
19	61	0.67	0.91	1	1.2	0.85	0.91	0.89	0.65	0.53	0.93	0.62	0.39
20	0.5	0.55	0.75	0.82	0.9	0.7	0.73	0.72	0.52	0.52	0.67	0.53	0.31
21	0.39	0.44	0.61	0.64	0.75	0.56	0.59	0.56	0.41	0.42	0.53	0.44	0.25
22	0.33	0.37	0.48	0.57	0.85	0.45	0.46	0.46	0.33	0.35	0.49	0.34	0.19
23	0.26	0.3	0.4	0.46	0.46	0.37	0.37	0.38	0.27	0.38	0.38	0.28	0.16
24	0.22	0.24	0.32	0.38	0.38	0.3	0.31	0.31	0.23	0.23	0.07	0.24	0.14
25	0.19	0.19	0.26	0.32	0.31	0.25	0.26	0.26	0.17	0.19	0.02	0.18	0.11
26	0.15	0.16	0.21	0.25	0.25	0.2	0.21	0.21	0.16	0.15		0.17	0.1
27	0.12	0.13	0.17	0.21	0.22	0.17	0.17	0.17	0.12	0.12		0.14	0.075
28	0.1	0.11	0.14	0.17	0.19	0.13	0.16		0.097	0.1		0.11	0.065

Table 11

Dome Water Column Percent Illumination Profile

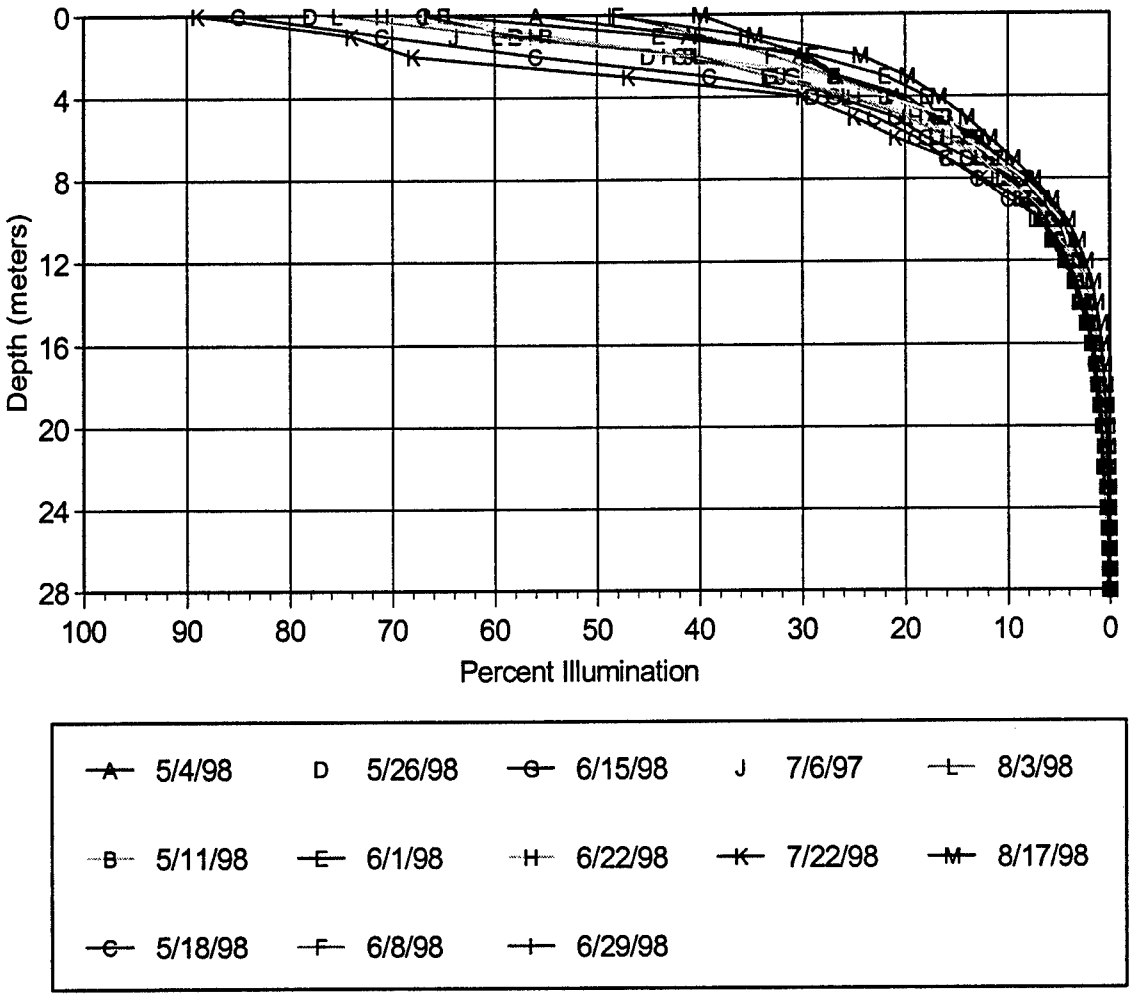

Figure 12

Nitrogen is an important nutrient in the development and growth of microorganisms living in Lake George. Nitrogen enters the water column from several sources. They are atmospheric deposition, surface runoff and groundwater, and fixation of atmospheric nitrogen by select microorganisms. This nitrogen is used in various roles in cell development such as manufacturing of nucleotides and amino acids.

Total nitrogen represents all of the fixed nitrogen in the water column to include all organic and inorganic forms. This concentration is measured by converting all nitrogen in the sample to nitrate and then measuring nitrate concentration as discussed previously in the Methods and Materials.

With the exception of the first sampling date (04 May) the total nitrogen concentration in the water column remained fairly uniform throughout the entire summer sampling period, in the range of 2 to 5 micromoles per liter at both sites. The initial reading is relatively high in comparison to all other sampling dates. Concentrations of nitrogen, particularly nitrate, are normally elevated immediately after snowmelt begins due to an HNO_3^- brine that builds up at the bottom of the snow-pack (Likens & Borman, 1995). This would not account for all of the increased concentration found on 04 May however, but when the sample was filtered through a .4 micron filter, the dissolved nitrogen concentration was similar to other dissolved nitrogen concentrations found during the sampling period (see figures 15 and 16).

Total Nitrogen Concentrations (*u*mol/L) – Site Hague

Depth	5/4/98	5/11/98	5/18/98	5/26/98	6/1/98	6/8/98	6/15/98	6/22/98	6/29/98	7/6/97	7/22/98	8/3/98	8/17/98
0	3.33	3.79	N/A	2.93	4.11	2.43	4.01	1.83	3.78	2.7	2.99	2.29	2.47
5	3.22	3.77	N/A	3.08	2.3	1.7	2.02	1.28	1.89	1.52	1.68	2.21	1.08
10	7.18	3.91	N/A	3.5	2.43	2.12	2.19	1.81	1.74	1.61	1.88	2.12	1.12
15	5.49	4.59	N/A	3.42	3.27	1.82	1.63	2.05	2.36	2	1.69	2.37	1.37
20	14	3.01	N/A	2.94	3.33	1.53	2.85	1.85	2	1.74	1.86	2.43	1.01
25	20.27	3.9	N/A	2.74	2.71	1.81	1.36	1.71	2.29	2.06	2.29	2.31	1.24

Table 12

Hague Total Nitrogen Concentration Profile

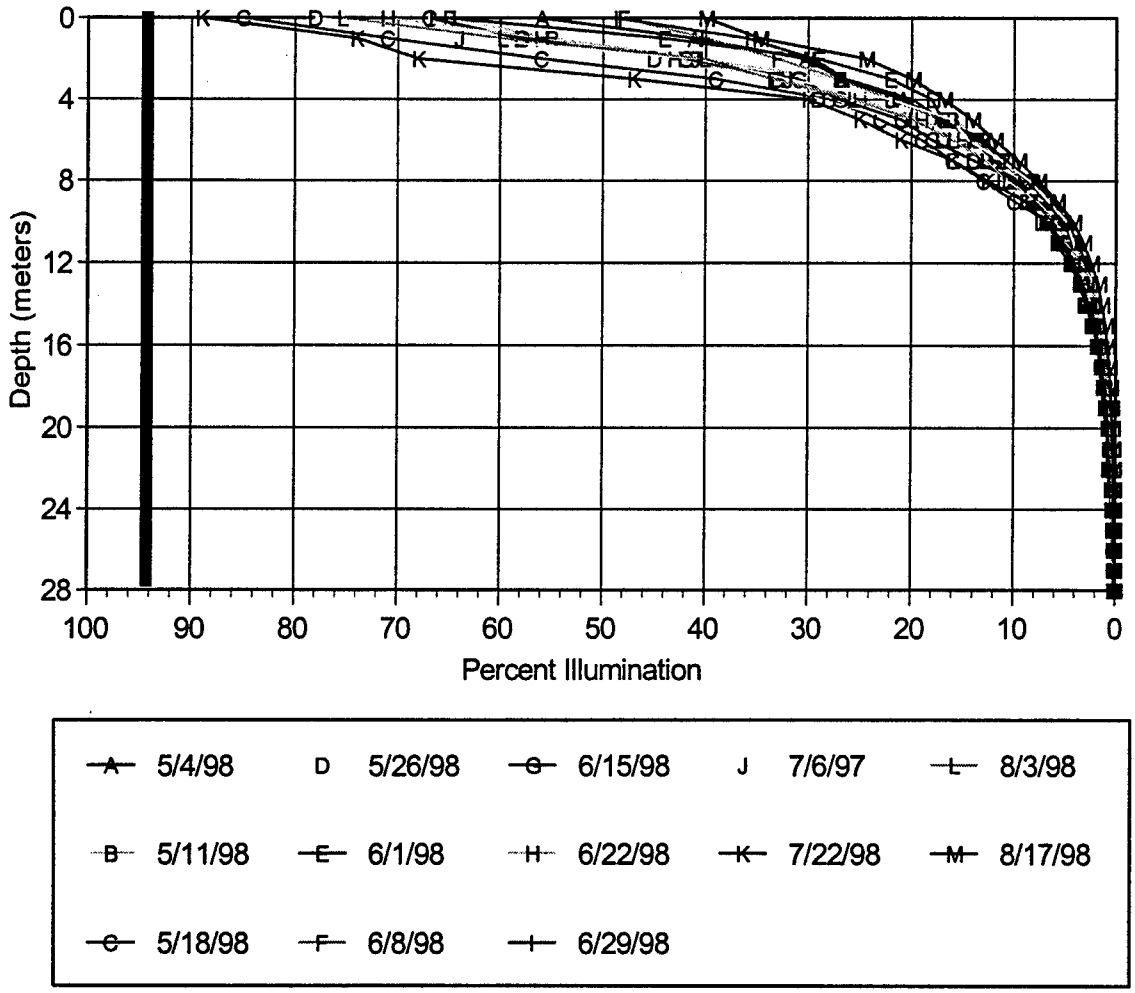

Figure 13

Total Nitrogen Concentrations (*u*mol/L) – Site Dome

Depth	5/4/98	5/11/98	5/18/98	5/26/98	6/1/98	6/8/98	6/15/98	6/22/98	6/29/98	7/6/97	7/22/98	8/3/98	8/17/98
0	12.49	4.12	N/A	3.23	2.43	1.52	2.02	1.25	2.13	2.12	2.48	2.48	1.43
5	13.27	3.78	N/A	3.1	2.69	1.35	1.49	1.43	1.79	1.66	1.74	2.33	1.21
10	12.64	4.88	N/A	5.16	3.17	1.28	1.27	1.49	2.11	2.14	2.18	2.79	1.47
15	9.77	4.75	N/A	3.17	3.04	1.96	0.84	1.89	2.36	2.38	2.22	2.42	1.23
20	10.82	4.47	N/A	4.4	2.68	1.56	1.79	2.2	2.47	2.24	2.01	2.47	1.16
25	9.54	3.95	N/A	3.49	2.11	2.31	1.41	1.85	2.43	1.96	2.81	2.75	1.71

Table 13

Dome Total Nitrogen Concentration Profile

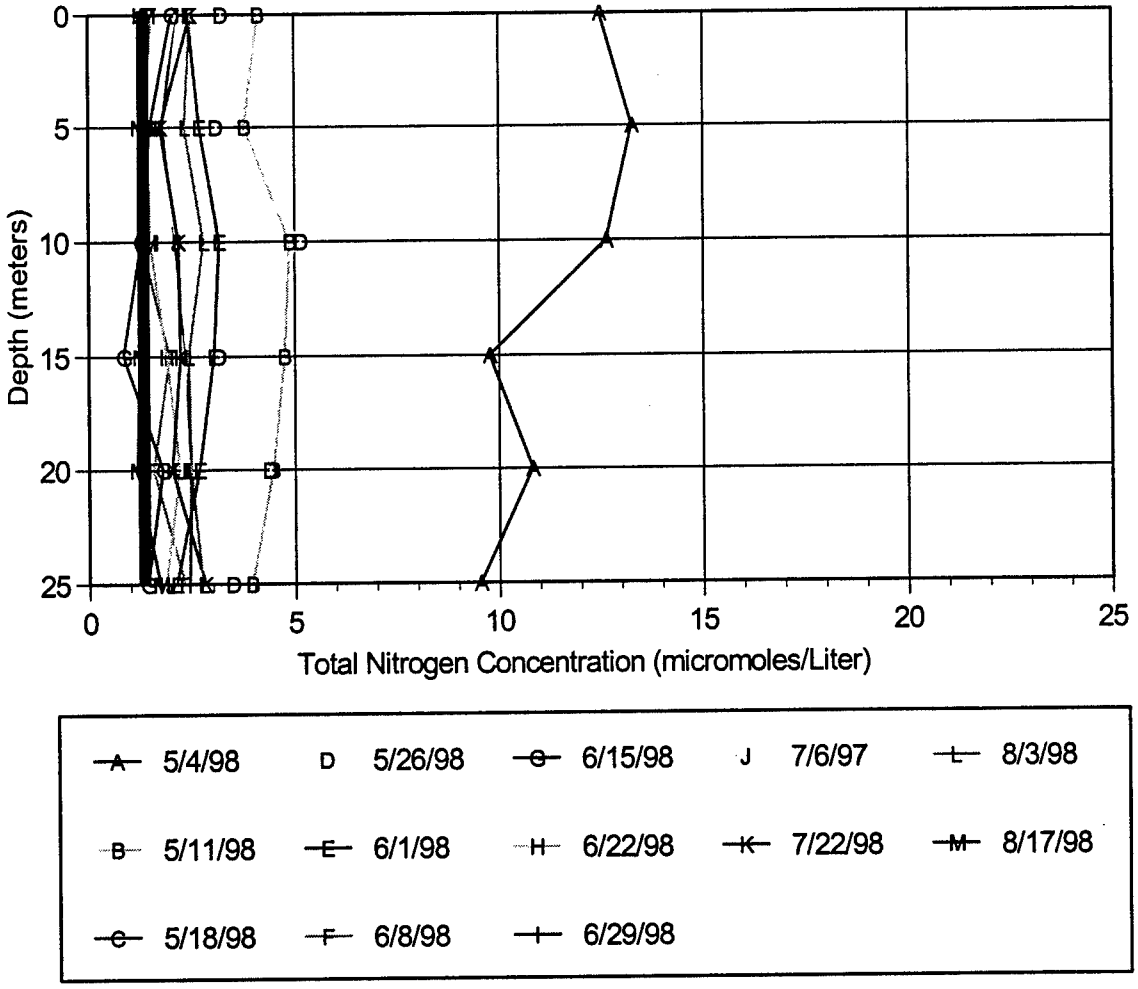

Figure 14

Dissolved nitrogen concentrations were the measure of nitrogen in a water sample that had previously been filtered through a .4 micron polycarbonate filter. This filtering process removed most of the large organisms, however some picophytoplankton and bacteria are small enough to pass through this size filter. These samples would contain inorganic nitrogen forms along with free organic molecules or peptides.

Dissolved nitrogen measurements also were fairly uniform throughout the water column with slightly higher concentrations at the surface and at 25 meters in depth. These dissolved nitrogen concentrations represented a major portion of the total nitrogen concentrations found in the water column.

Particulate nitrogen concentrations were determined by the difference in total nitrogen and dissolved nitrogen (**Particulate Nitrogen = Total Nitrogen – Dissolved Nitrogen**).

Dissolved Nitrogen Concentrations (*u*mol/L) – Site Hague

Depth	5/4/98	5/11/98	5/18/98	5/26/98	6/1/98	6/8/98	6/15/98	6/22/98	6/29/98	7/6/97	7/22/98	8/3/98	8/17/98
0	2.22	2.08	1.88	2.04	4.02	2.04	1.91	3.14	2.47	2.51	2.06	2.63	1.85
5	1.61	0.84	1.92	1.67	1.93	1.61	1.51	1.49	1.8	1.75	1.97	1.84	1.27
10	1.39	1.08	1.74	1.64	1.87	1.62	1.35	1.61	1.73	1.97	1.9	1.78	1.41
15	1.29	0.75	1.75	1.53	1.84	1.57	1.33	1.57	1.94	2.06	1.78	1.98	1.49
20	1.38	0.81	1.68	1.55	1.78	1.5	1.08	1.53	1.95	1.93	1.69	2	1.4
25	1.35	0.95	2	1.61	1.81	1.74	1.39	1.65	1.91	2.37	2	1.95	1.57

Table 14

Hague Dissolved Nitrogen Concentration Profile

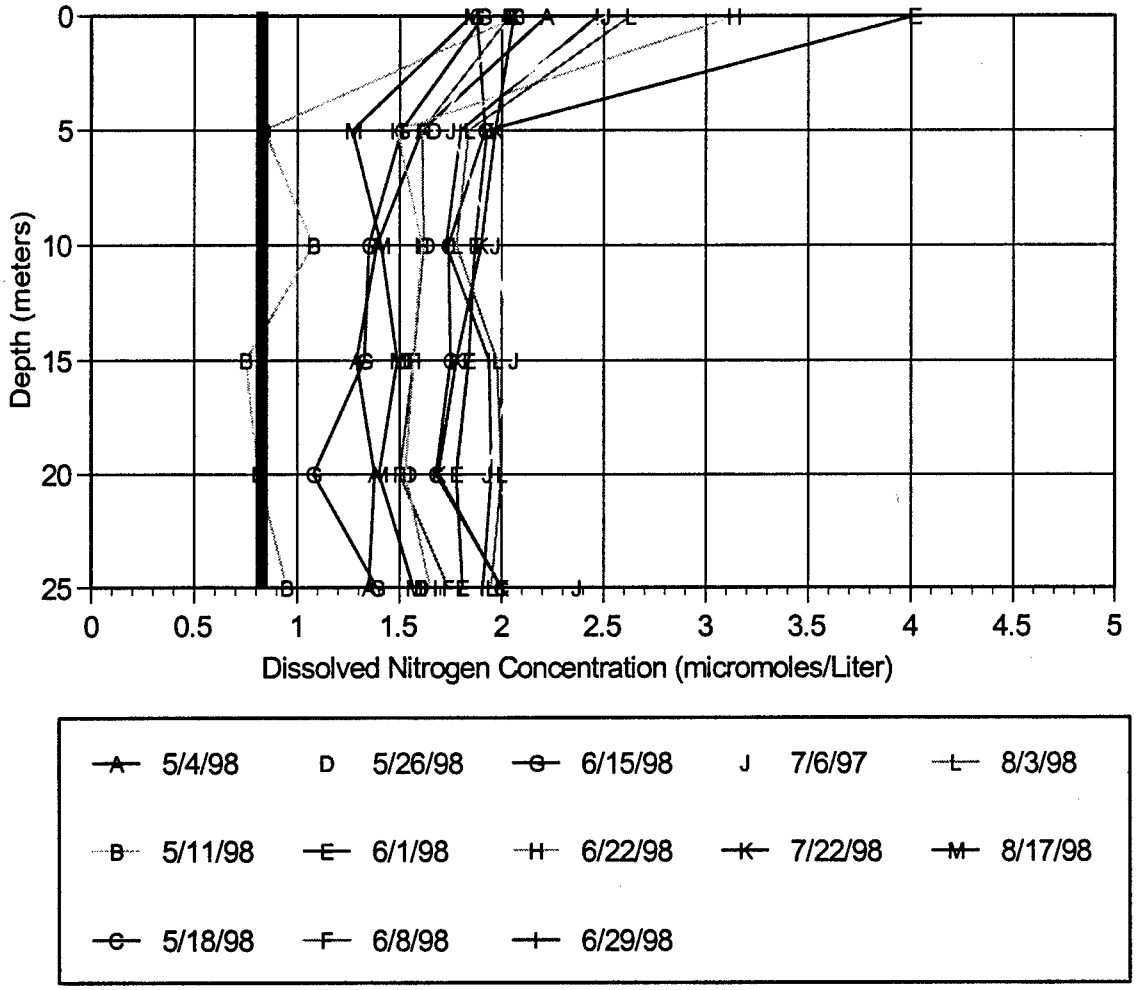

Figure 15

Dissolved Nitrogen Concentrations (*u*mol/L) – Site Dome

Depth	5/4/98	5/11/98	5/18/98	5/26/98	6/1/98	6/8/98	6/15/98	6/22/98	6/29/98	7/6/97	7/22/98	8/3/98	8/17/98
0	1.4	0.93	1.8	2.04	1.66	1.92	0.69	1.31	2.07	2.21	2.14	2.71	1.72
5	1.12	0.79	1.7	1.55	1.55	1.42	0.67	1.36	1.86	1.99	1.58	1.85	1.45
10	1.24	0.68	1.66	1.52	1.59	1.49	0.73	1.36	1.93	1.99	1.6	1.79	1.53
15	1.33	0.6	1.73	1.58	1.78	1.71	0.78	1.54	2.17	2.29	1.6	1.74	1.29
20	1.34	1.48	1.77	1.67	1.89	1.77	1.16	1.56	2.36	2.44	1.93	1.88	1.31
25	1.61	0.82	1.79	1.75	2.04	1.67	0.98	1.82	2.1	2.45	1.63	2.12	1.71

Table 15

Dome Dissolved Nitrogen Concentration Profile

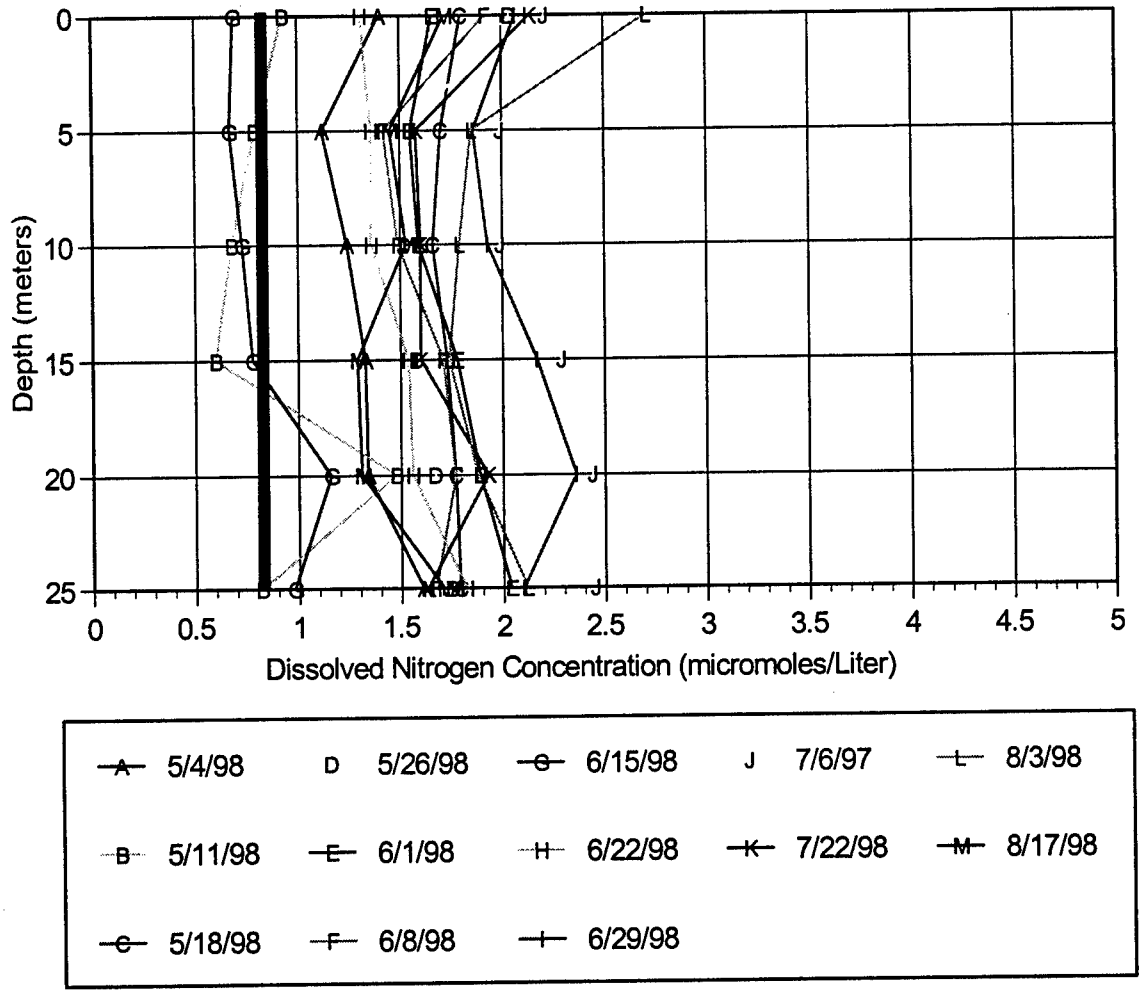

Figure 16

Particulate Nitrogen Concentrations (*u*mol/L) – Site Hague

Depth	5/4/98	5/11/98	5/18/98	5/26/98	6/1/98	6/8/98	6/15/98	6/22/98	6/29/98	7/6/97	7/22/98	8/3/98	8/17/98
0	1.11	1.71	N/A	0.89	0.09	0.39	2.1	-1.31	1.31	0.19	0.93	-0.34	0.62
5	1.61	2.93	N/A	1.41	0.37	0.09	0.51	-0.21	0.09	-0.23	-0.29	0.37	-0.19
10	5.79	2.83	N/A	1.86	0.56	0.5	0.84	0.2	0.01	-0.36	-0.02	0.34	-0.29
15	4.2	3.84	N/A	1.89	1.43	0.25	0.3	0.48	0.42	-0.06	-0.09	0.39	-0.12
20	12.62	2.2	N/A	1.39	1.55	0.03	1.77	0.32	0.05	-0.19	0.17	0.43	-0.39
25	18.92	2.95	N/A	1.13	0.9	0.07	-0.03	0.06	0.38	-0.31	0.29	0.36	-0.33

Table 16

Hague Particulate Nitrogen Concentration Profile

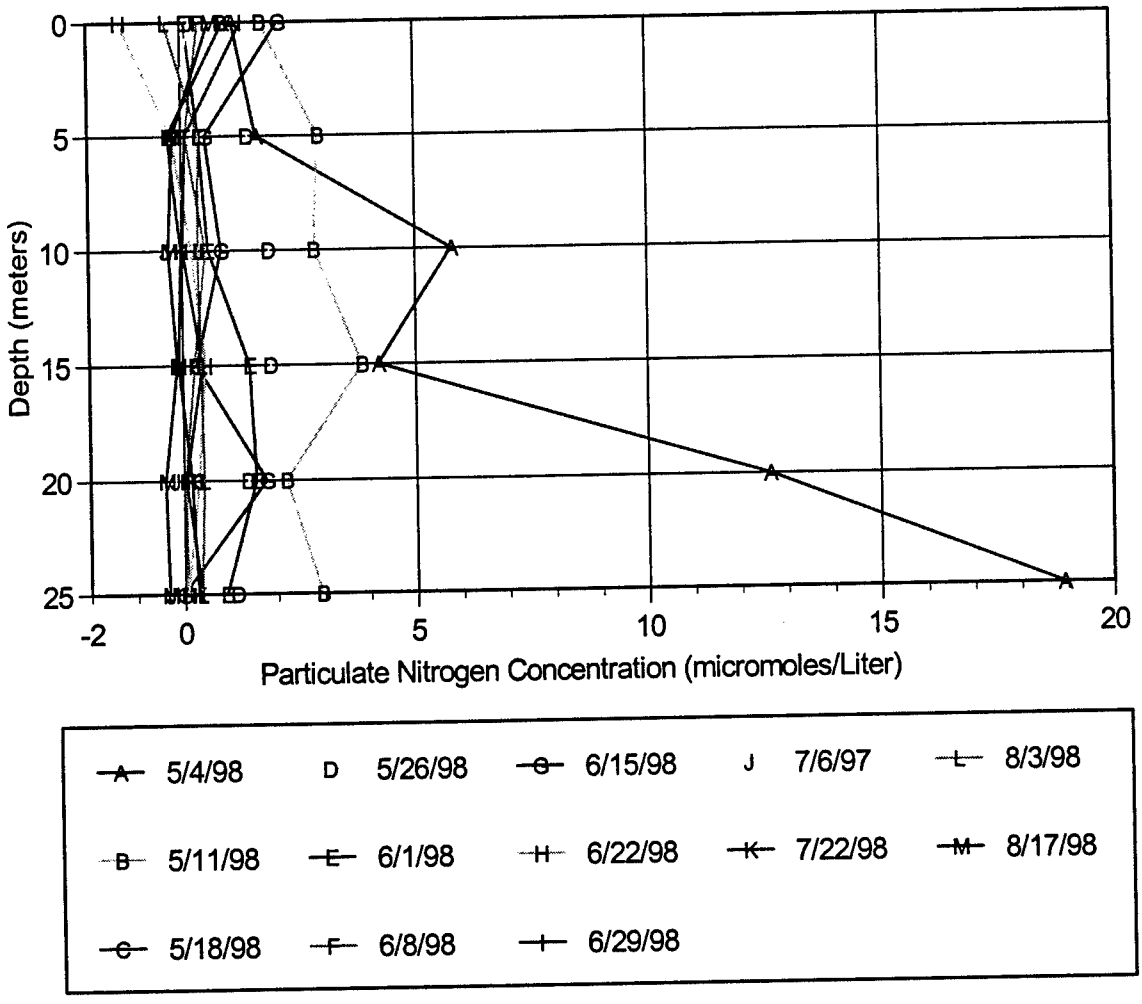

Figure 17

Particulate Nitrogen Concentrations (*u*mol/L) – Site Dome

Depth	5/4/98	5/11/98	5/18/98	5/26/98	6/1/98	6/8/98	6/15/98	6/22/98	6/29/98	7/6/97	7/22/98	8/3/98	8/17/98
0	11.09	3.19	N/A	1.19	0.77	-0.4	1.33	-0.06	0.06	-0.09	0.34	-0.23	-0.29
5	12.15	2.99	N/A	1.55	1.14	-0.07	0.82	0.07	-0.07	-0.33	0.16	0.48	-0.24
10	11.4	4.2	N/A	3.64	1.58	-0.21	0.54	0.13	0.18	0.15	0.58	1	-0.06
15	8.44	4.15	N/A	1.59	1.26	0.25	0.06	0.35	0.19	0.09	0.62	0.68	-0.06
20	9.48	2.99	N/A	2.73	0.79	-0.21	0.63	0.64	0.11	-0.2	0.08	0.59	-0.15
25	7.93	3.13	N/A	1.74	0.07	0.64	0.43	0.03	0.33	-0.49	1.18	0.63	0

Table 17

Dome Particulate Nitrogen Concentration Profile

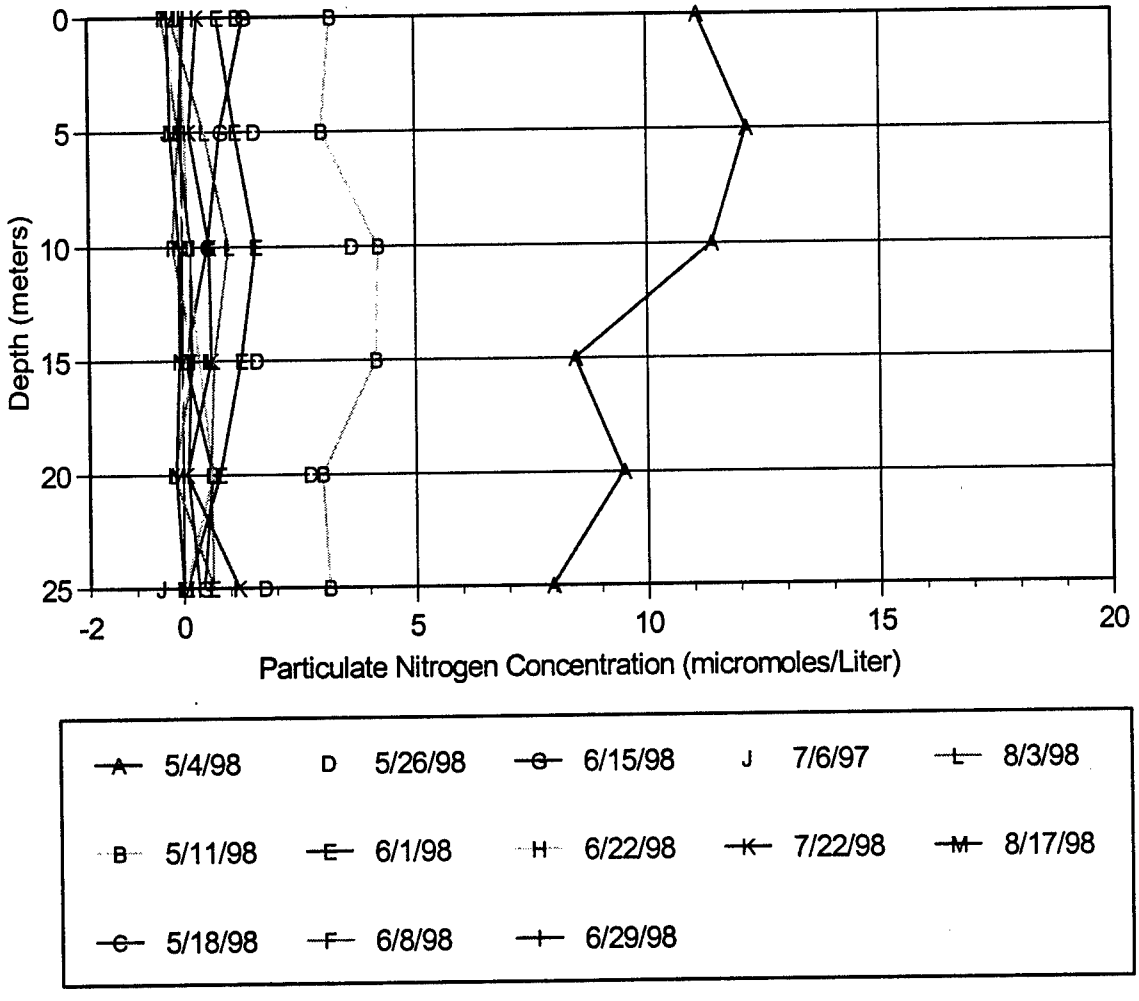

Figure 18

Urea is the soluble breakdown product of proteins and amino acids (Henderson's Dictionary of Biological Terms). Some picophytoplankton are able to use this as a nitrogen source (Collier, 1998). This chemical makes up part of the previously reported concentrations for total nitrogen and dissolved nitrogen.

Urea was found in greatest concentration near the surface at each site. Most urea concentrations were found in the neighborhood of 0.1 to 0.2 micromoles per liter, however a concentration as great as 1.6 micromoles per liter was found at the surface at Site Hague on the 17 Aug sampling date.

Urea Concentrations (*u*mol/L) – Site Hague

Depth	5/4/98	5/11/98	5/18/98	5/26/98	6/1/98	6/8/98	6/15/98	6/22/98	6/29/98	7/6/97	7/22/98	8/3/98	8/17/98
0	0.9	0.76	0.17	0.76	0.38	0.64	0.31	0.36	1.12	0.85	0.68	0.12	1.59
5	0.29	0.43	0.25	0	0.06	0.16	0.17	0.24	0	0.11	0.16	0.07	0.16
10	0.12	0.57	0.2	0	0.12	0.15	0.12	0.27	0.1538	0.14	0	0	0.03
15	0.18	0.73	0.21	0	0.27	0.34	0.25	0.22	0.2385	0.24	0.3	0.11	0.22
20	1.13	0	0.24	0.14	0.27	0.4	0.23	0.32	0.1921	0.25	0.19	0.08	0.12
25	0.77	0	0.18	0.13	0.11	0.28	0.26	0.21	0.1624	0.22	0.19	0.17	0.14

Table 18

Hague Urea Concentration Profile

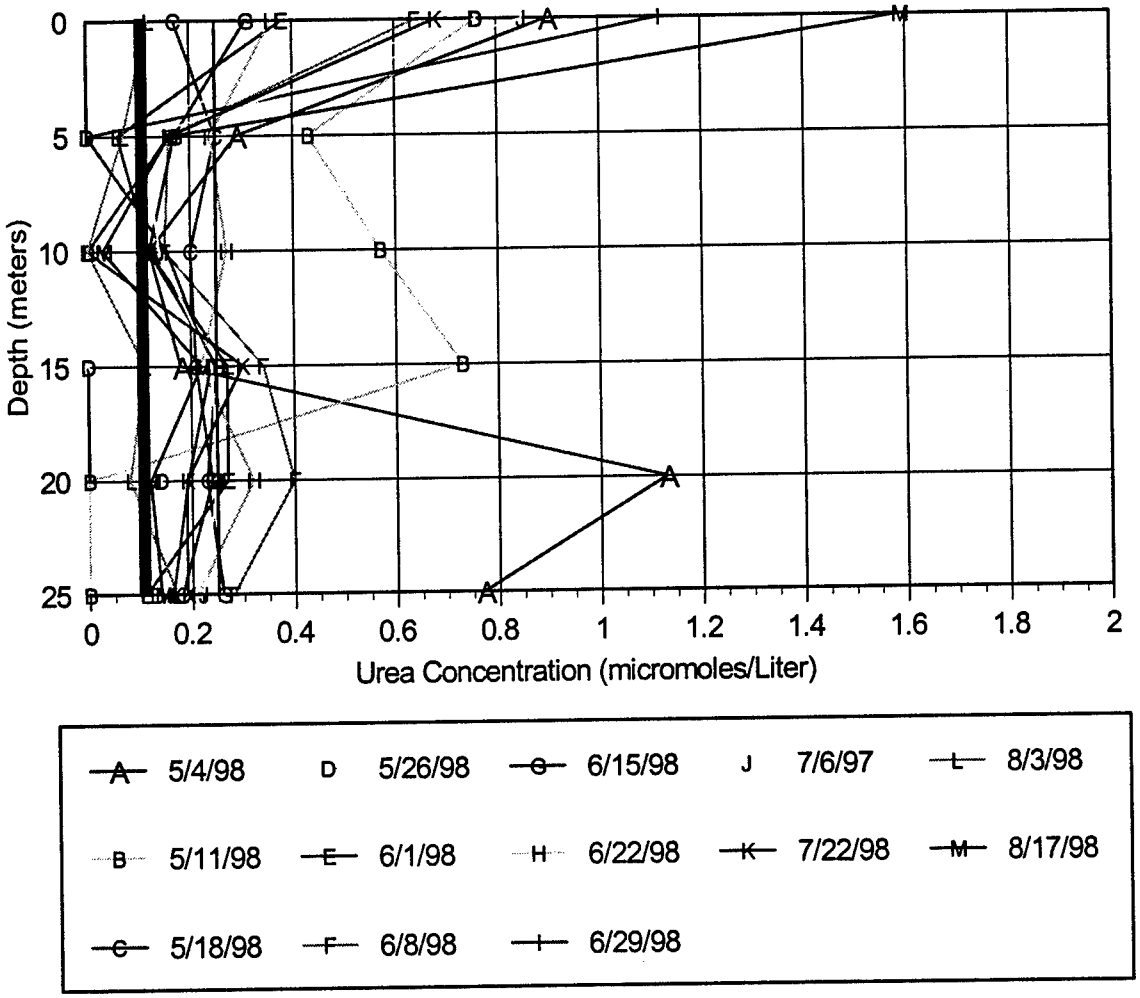

Figure 19

Urea Concentrations (*u*mol/L) – Site Dome

Depth	5/4/98	5/11/98	5/18/98	5/26/98	6/1/98	6/8/98	6/15/98	6/22/98	6/29/98	7/6/97	7/22/98	8/3/98	8/17/98
0	0.52	0.61	0.27	0.27	0.23	0.2	0.12	0.24	0.3352	0.19	0.99	0.19	0.41
5	0.13	0.14	0.18	0.19	0.12	0.16	0.16	0.08	0	0.09	0	0.11	0.04
10	0.13	0.17	0.14	0.17	0.05	0.18	0.14	0.17	0.1065	0.15	0	0.13	0.07
15	0.42	0.25	0.21	0.23	0.11	0.24	0.4	0.21	0.152	0.21	0.08	0.06	0.08
20	0.12	0.24	0.38	0.24	0.18	0.24	0.29	0.23	0.2931	0.27	0.04	0.17	0.18
25	0.24	0.2	0.37	0.2	0.2	0.16	0.16	0.23	0.1355	0.23	0.2	0.18	0.14

Table 19

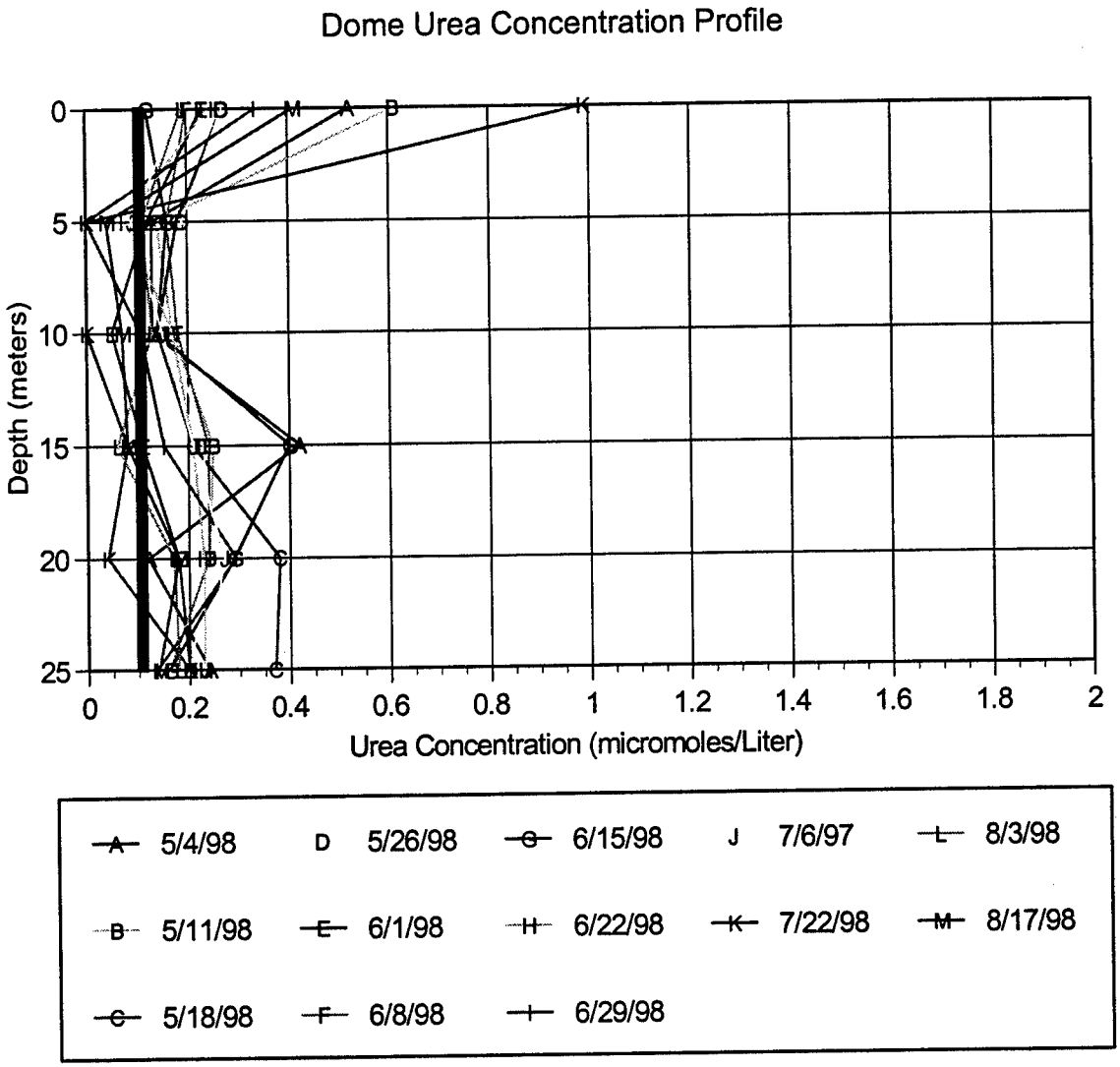

Figure 20

Ammonia is also a product of the breakdown of organic material by heterotrophic bacteria and in aqueous environments is found mainly in the form of ammonium (NH_4^+) (Wetzel, 1975). Ammonium also can be used as a nitrogen source for picophytoplankton. It is normally found in low concentrations, but does build up in the hypolimnion of lakes when the lake stratifies during the summer months.

This pattern outlined by Wetzel was seen in Lake George during the sampling period. There were low concentrations at both sites during the summer in the upper depths of the water column and also there was a build up of ammonium in the hypolimnion during this same period. Both sites were fairly similar in their ammonium profiles in the epilimnion and metalimnion, however in the hypolimnion at Site Dome there were larger concentrations of ammonium found.

Ammonium Concentrations (*u*mol/L) – Site Hague

Depth	5/4/98	5/11/98	5/18/98	5/26/98	6/1/98	6/8/98	6/15/98	6/22/98	6/29/98	7/6/97	7/22/98	8/3/98	8/17/98
0	0.4	0.29	0.35	0.46	0.33	0.39	0.21	0.35	0.2426	0	0.34	0.22	0.12
5	0	0.08	0.46	0.38	0.33	0.27	0.19	0.05	0.169	0	0	0.05	0.08
10	0	0.08	0.26	0.32	0.26	0.18	0.02	0.28	0.3399	0.13	0.06	0	0.01
15	0	0.29	0.03	0.28	0.35	0.39	0.56	0.47	0.5545	0.29	0	0.22	0.04
20	0	0.32	0.14	0.29	0.42	0.37	0.07	0.41	0.6736	0.37	0.53	0.18	0.01
25	0.06	0.71	0.18	0.32	0.47	0.57	0.5	0.59	0.8808	0.79	0.63	0.53	0.68

Table 20

Hague Ammonium Concentration Profile

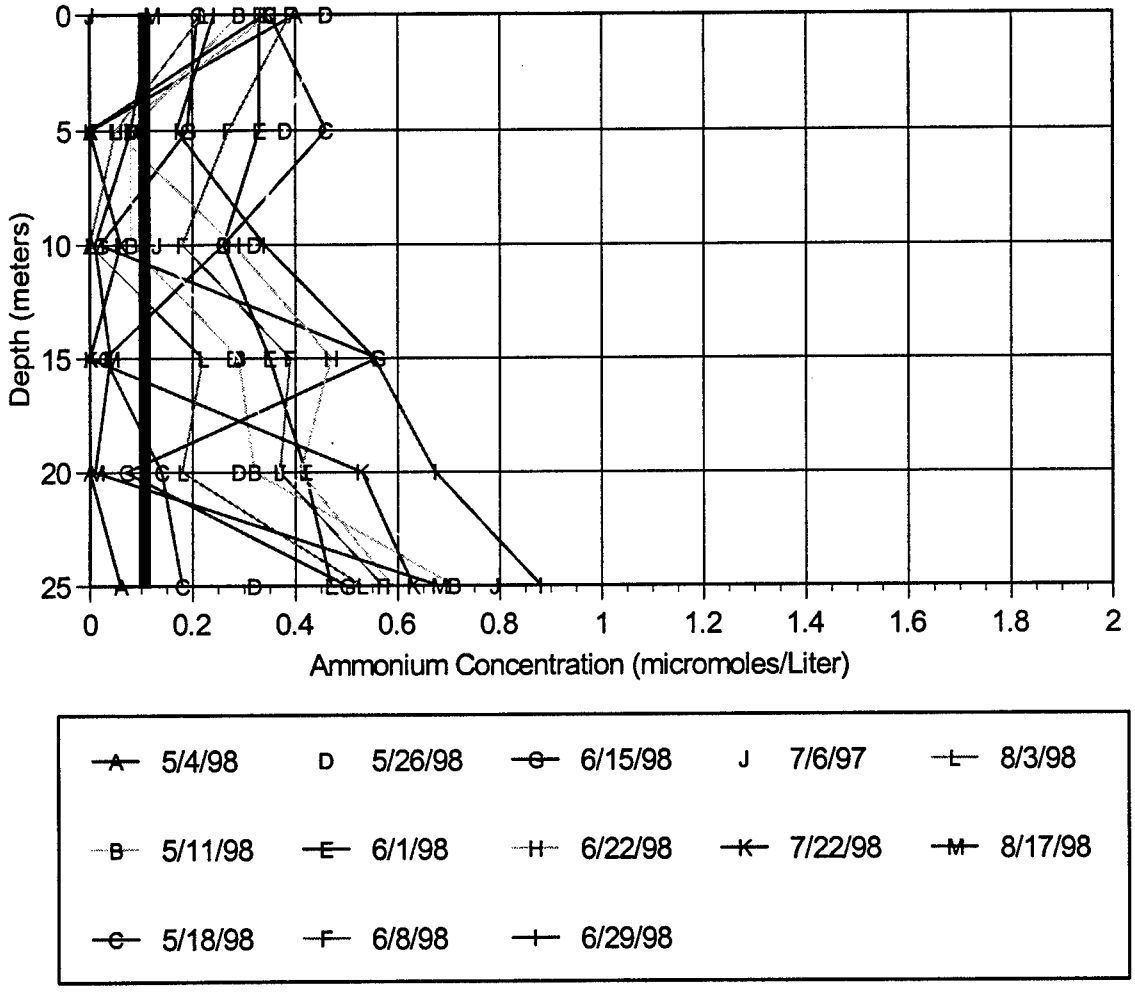

Figure 21

Ammonium Concentrations (*u*mol/L) – Site Dome

Depth	5/4/98	5/11/98	5/18/98	5/26/98	6/1/98	6/8/98	6/15/98	6/22/98	6/29/98	7/6/97	7/22/98	8/3/98	8/17/98
0	0.18	0.26	0.25	0.16	0.19	0.11	0.12	0	0.1052	0.05	0	0.07	0.11
5	0	0.12	0.15	0.1	0.1	0.1	0.05	0.04	0.1185	0	0	0.04	0.08
10	0	0.14	0.08	0.15	0.2	0.38	0.16	0.1	0.2489	0.1	0	0.05	0.07
15	0.12	0.43	0.12	0.29	0.46	0.63	0.44	0.79	0.7956	1.06	0.24	0.16	0.08
20	0.24	0.51	0.28	0.48	0.74	0.77	0.83	0.82	1.4491	1.04	2	0.56	0.08
25	0.3	0.74	0.35	0.65	0.84	0.87	0.93	1.45	1.609	1.25	1.17	1.29	0.51

Table 21

Dome Ammonium Concentration Profile

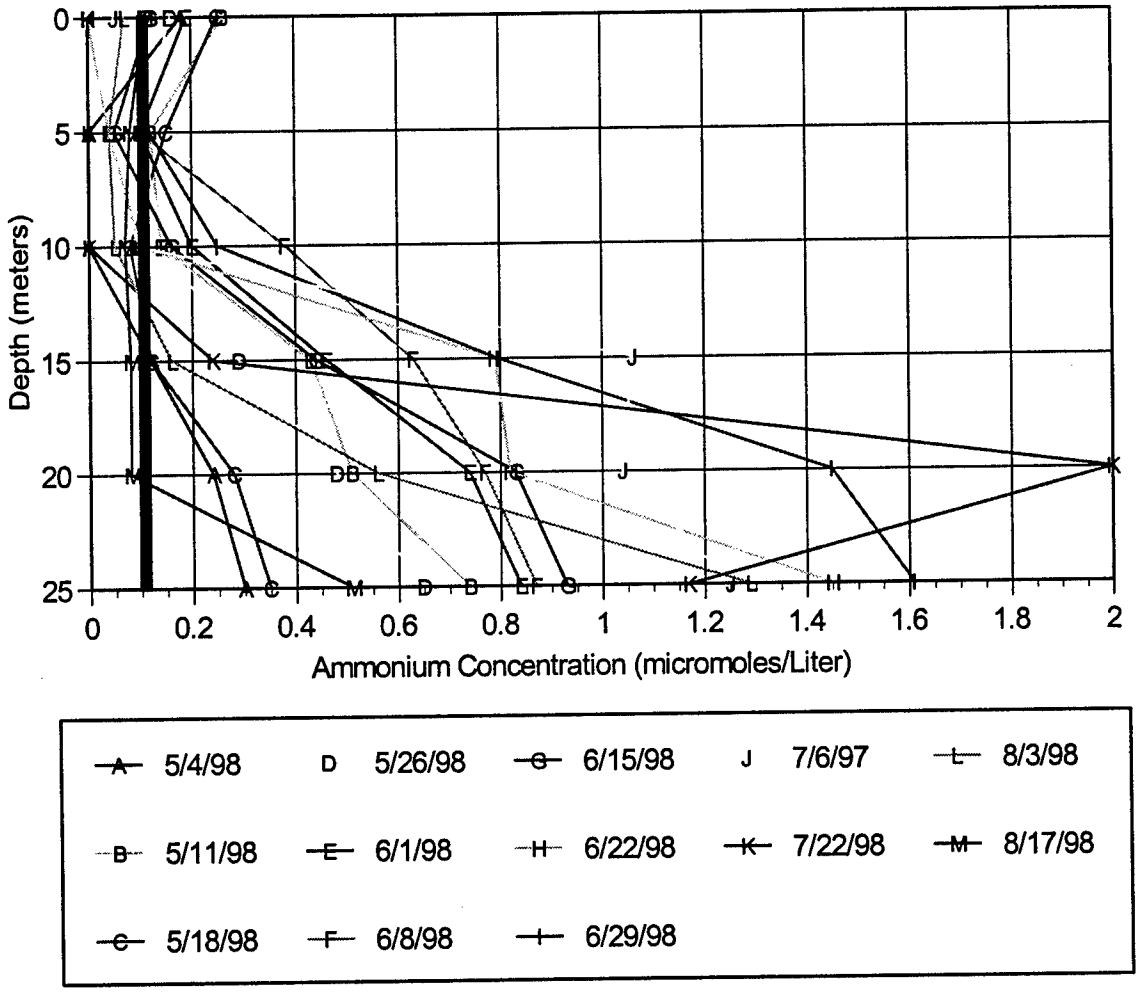

Figure 22

Nitrite and nitrate are both possible nitrogen sources found in the water column of Lake George. Nitrate can enter the water column through surface run-off and ground water, along with atmospheric deposition in the form of rain or dry deposition. Nitrite and nitrate are also the products of a two-step bacteria mediated transformation involving the oxidation of ammonium to nitrate known as nitrification.

The measurements listed as nitrite and nitrate are represented in this fashion because of the method of detection used by the Latchet Auto-analysis System. Nitrite is first measured with a cadmium reduction column switched off. Next samples are measured after passing through a cadmium reduction column that reduces all the nitrate in a sample to nitrite, and the concentration of nitrite is then measured. Nitrate levels alone were determined by difference using the nitrite and combined nitrite/nitrate concentrations (**Nitrate = Nitrite/Nitrate Combined – Nitrite**).

Nitrite levels in Lake George are extremely low and no pattern could be found in their concentrations at different depths in the water column at either site. Nitrate concentrations on the other hand showed the same pattern as ammonium with a build up of nitrate in the hypolimnion during the summer after the stratification of the water column.

Nitrite Concentrations (*u*mol/L) – Site Hague

Depth	5/4/98	5/11/98	5/18/98	5/26/98	6/1/98	6/8/98	6/15/98	6/22/98	6/29/98	7/6/97	7/22/98	8/3/98	8/17/98
0	0.07	0	0	0.06	0.11	0.06	0.07	0.04	0	0	0	0.05	0.06
5	0.08	0.06	0.06	0.06	0.07	0	0.07	0.05	0	0	0	0.04	0.06
10	0.05	0.08	0.07	0.07	0.07	0.07	0.07	0.05	0	0	0.04	0.04	0.06
15	0.06	0.08	0.05	0.06	0.08	0.05	0.06	0.03	0	0	0.04	0.05	0.07
20	0.08	0.08	0.06	0.06	0.1	0	0.06	0.04	0.04	0	0.04	0.05	0.06
25	0.05	0.01	0.06	0.06	0.08	0	0.07	0.05	0	0.03	0.05	0.06	0.07

Table 22

Hague Nitrite Concentration Profile

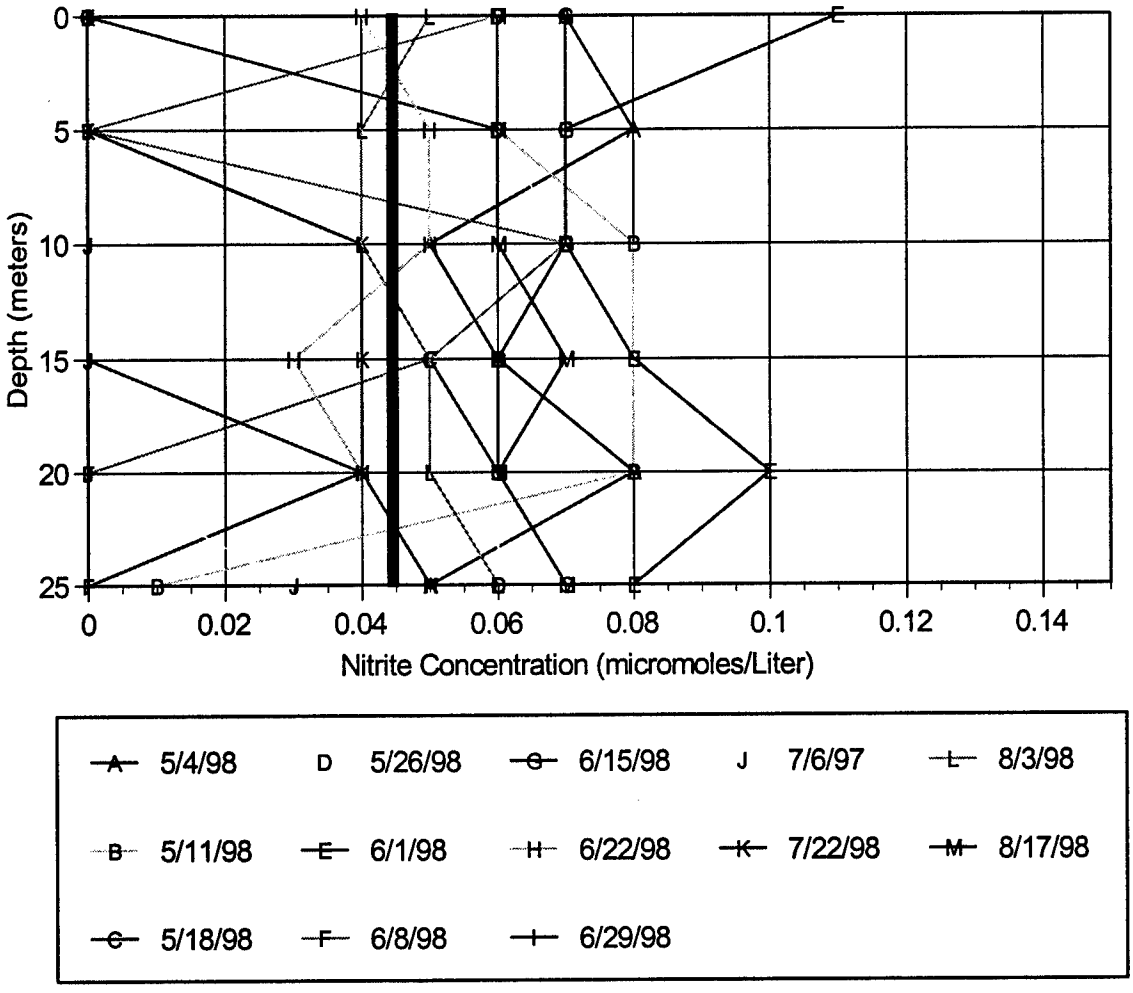

Figure 23

Nitrite Concentrations (*u*mol/L) – Site Dome

Depth	5/4/98	5/11/98	5/18/98	5/26/98	6/1/98	6/8/98	6/15/98	6/22/98	6/29/98	7/6/97	7/22/98	8/3/98	8/17/98
0	0.07	0.07	0.06	0.1	0.11	0.1	0.07	0	0	0	0.05	0.05	0.07
5	0.06	0.09	0.07	0.05	0.06	0	0.07	0.03	0	0	0.06	0.04	0.07
10	0.06	0.01	0.08	0.06	0.13	0	0.05	0	0	0.04	0.05	0.04	0.06
15	0.06	0.06	0.06	0.05	0.11	0.05	0.06	0.03	0.04	0.07	0.04	0.06	0.06
20	0.07	0.06	0.06	0.1	0.07	0.05	0.06	0.03	0.03	0.05	0.05	0.05	0.06
25	0.05	0.01	0.06	0.04	0.09	0	0.06	0.06	0.03	0.05	0.05	0.08	0.08

Table 23

Dome Nitrite Concentration Profile

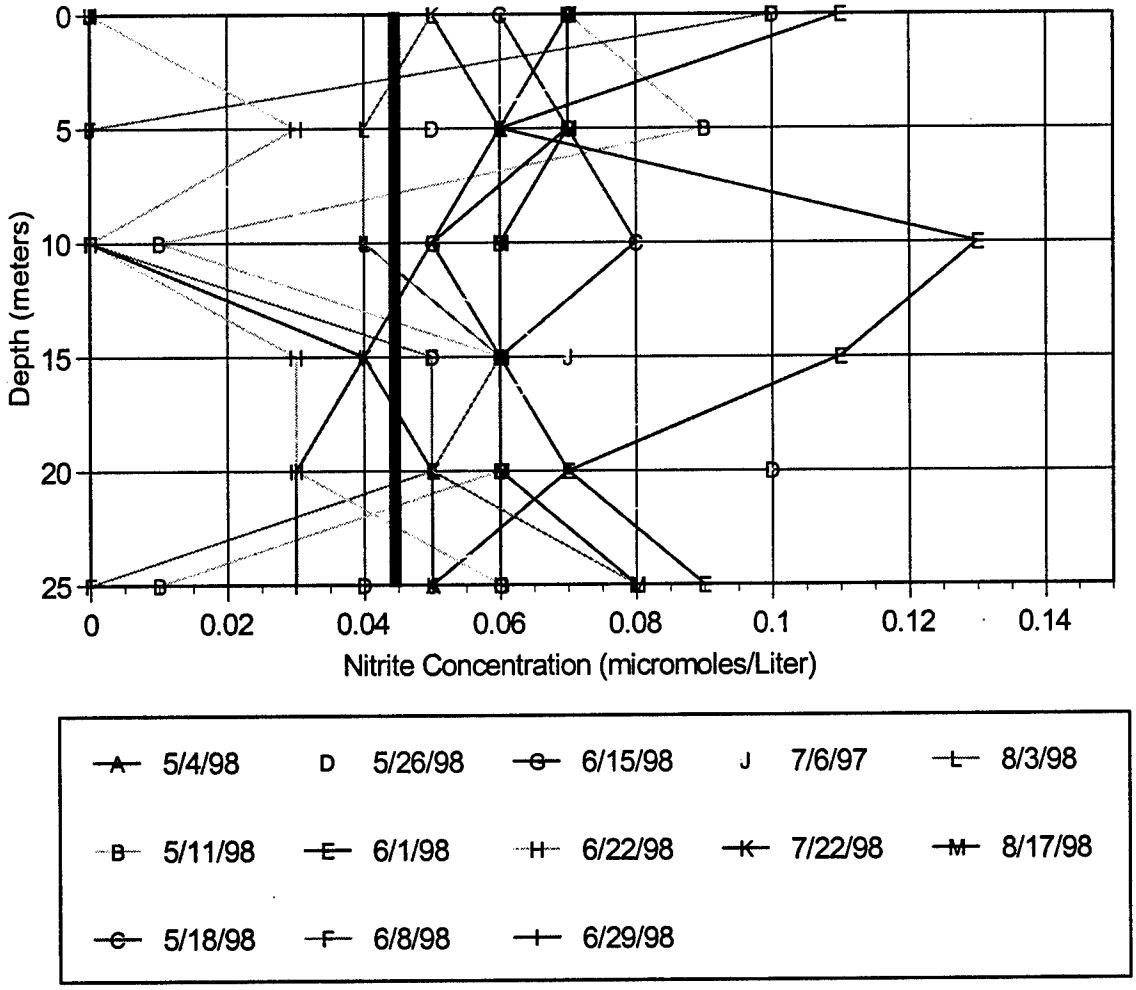

Figure 24

Nitrite and Nitrate Concentrations (*u*mol/L) – Site Hague

Depth	5/4/98	5/11/98	5/18/98	5/26/98	6/1/98	6/8/98	6/15/98	6/22/98	6/29/98	7/6/97	7/22/98	8/3/98	8/17/98
0	0.22	0.26	0.19	0.15	0.14	0.09	0.02	0.06	0.07	0.04	0.07	0.05	0.06
5	0.16	0.26	0.18	0.26	0.09	0.09	0.02	0	0.04	0	0.04	0.04	0.04
10	0.18	0.25	0.18	0.14	0.14	0.09	0.02	0.04	0.05	0.04	0.04	0.06	0.05
15	0.21	0.21	0.17	0.11	0.1	0.12	0.2	0.14	0.12	0.15	0.06	0.05	0.03
20	0.26	0.37	0.29	0.21	0.19	0.19	0.24	0.19	0.17	0.19	0.11	0.07	0.06
25	0.2	0.44	0.33	0.27	0.36	0.31	0.58	0.25	0.33	0.46	0.19	0.19	0.26

Table 24

Hague Nitrite/Nitrate Concentration Profile

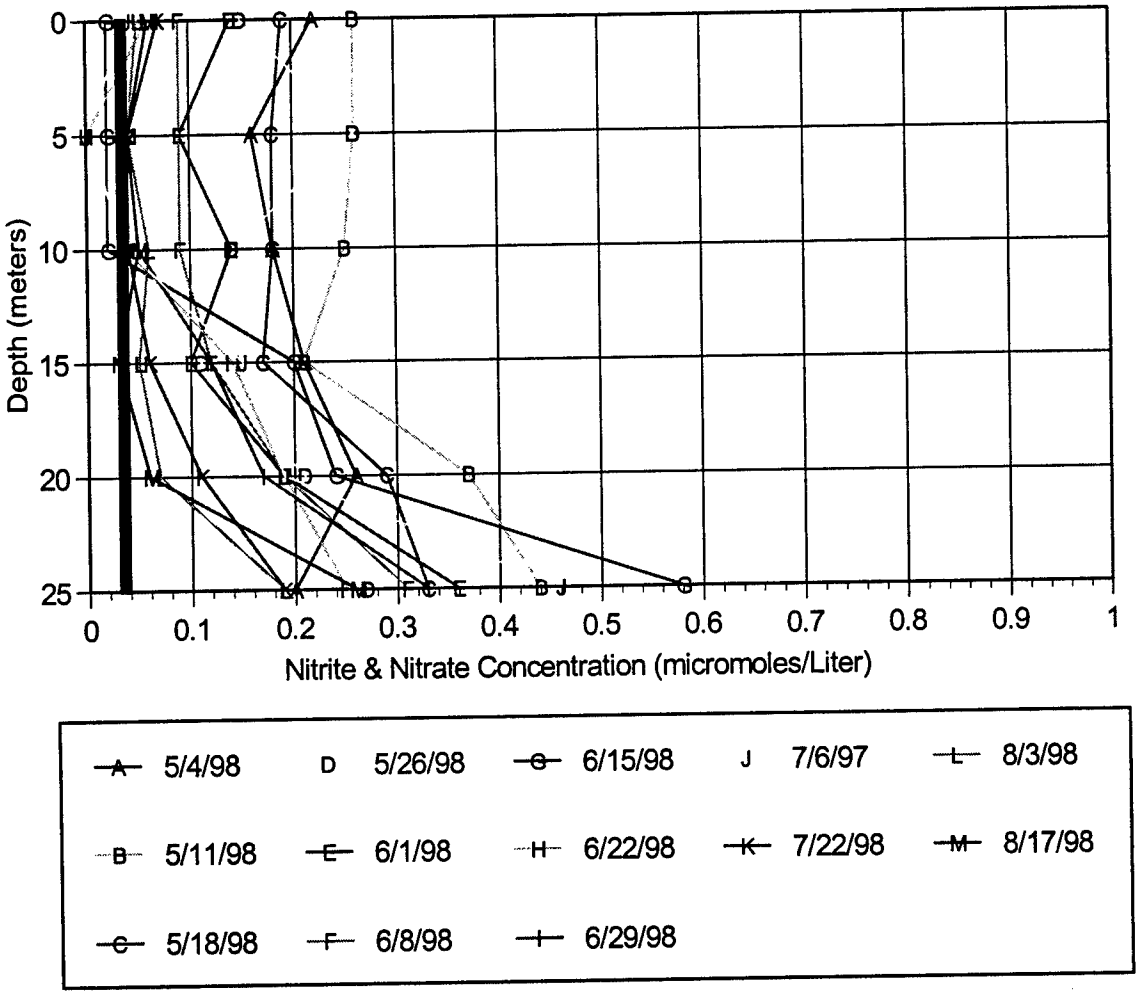

Figure 25

Nitrite and Nitrate Concentrations (*u*mol/L) – Site Dome

Depth	5/4/98	5/11/98	5/18/98	5/26/98	6/1/98	6/8/98	6/15/98	6/22/98	6/29/98	7/6/97	7/22/98	8/3/98	8/17/98
0	0.18	0.27	0.26	0.17	0.09	0.24	N/A	0	0.03	0.05	0.13	0.17	0.23
5	0.24	0.27	0.19	0.14	0.14	0.08	N/A	0.04	0.03	0.05	0.04	0.06	0.04
10	0.2	0.3	0.18	0.14	0.11	0.15	N/A	0.04	0.03	0.06	0.06	0.05	0.08
15	0.18	0.34	0.25	0.14	0.38	0.26	N/A	0.24	0.14	0.28	0.14	0.05	0.09
20	0.28	0.43	0.32	0.29	0.11	0.34	N/A	0.32	0.4	0.44	0.37	0.32	0.21
25	0.4	0.56	0.39	0.35	0.37	0.43	N/A	0.52	0.45	0.47	0.24	0.48	0.53

Table 25

Dome Nitrite/Nitrate Concentration Profile

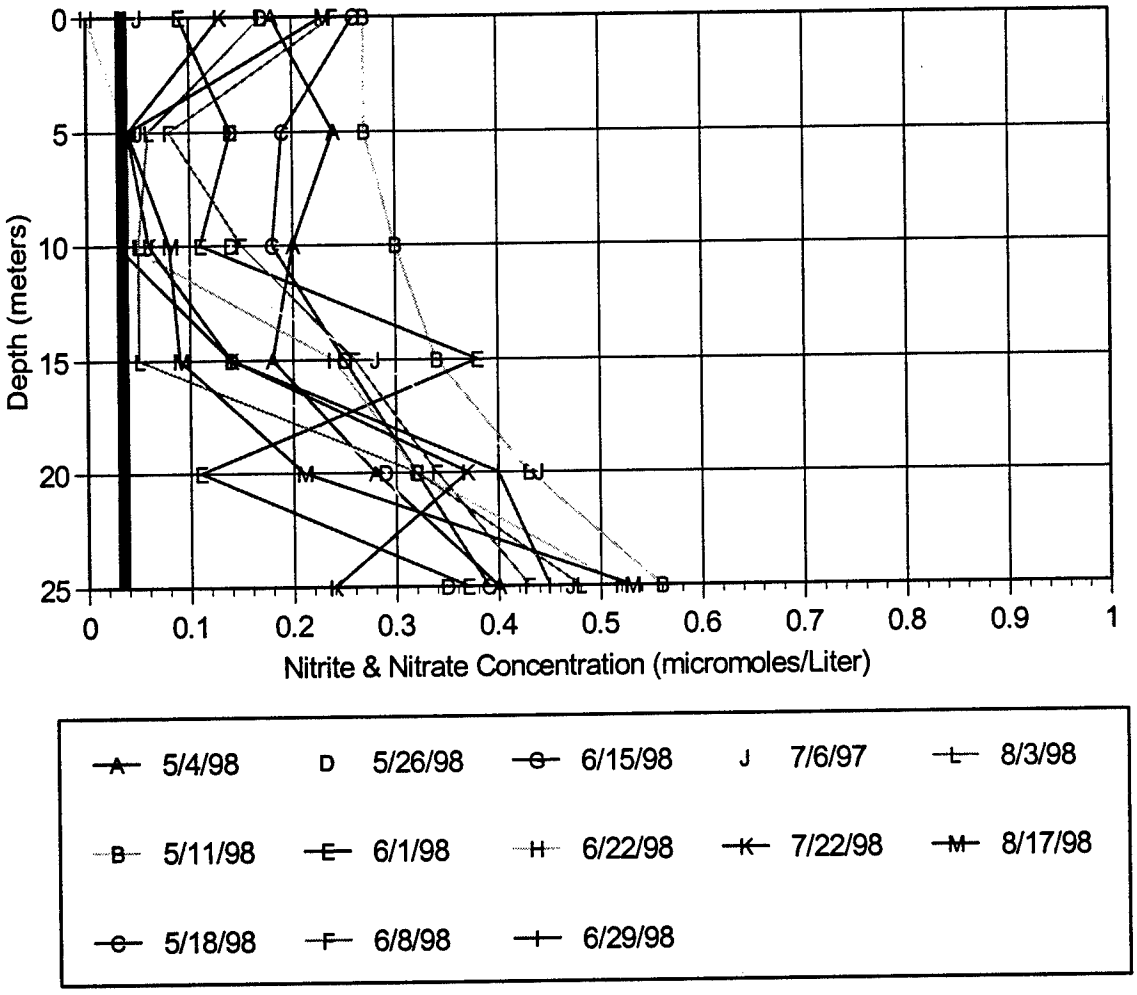

Figure 26

Nitrate Concentrations (*u*mol/L) – Site Hague

Depth	5/4/98	5/11/98	5/18/98	5/26/98	6/1/98	6/8/98	6/15/98	6/22/98	6/29/98	7/6/97	7/22/98	8/3/98	8/17/98
0	0.15	0.26	0.19	0.09	0.03	0.03	-0.05	0.02	0.07	0.04	0.07	0	0
5	0.08	0.2	0.12	0.2	0.02	0.09	-0.05	-0.05	0.04	0	0.04	0	-0.02
10	0.13	0.17	0.11	0.07	0.07	0.02	-0.05	-0.01	0.05	0.04	0	0.02	-0.01
15	0.15	0.13	0.12	0.05	0.02	0.07	0.14	0.11	0.12	0.15	0.02	0	-0.04
20	0.18	0.29	0.23	0.15	0.09	0.19	0.18	0.15	0.13	0.19	0.07	0.02	0
25	0.15	0.43	0.27	0.21	0.28	0.31	0.51	0.2	0.33	0.43	0.14	0.13	0.19

Table 26

Hague Nitrate Concentration Profile

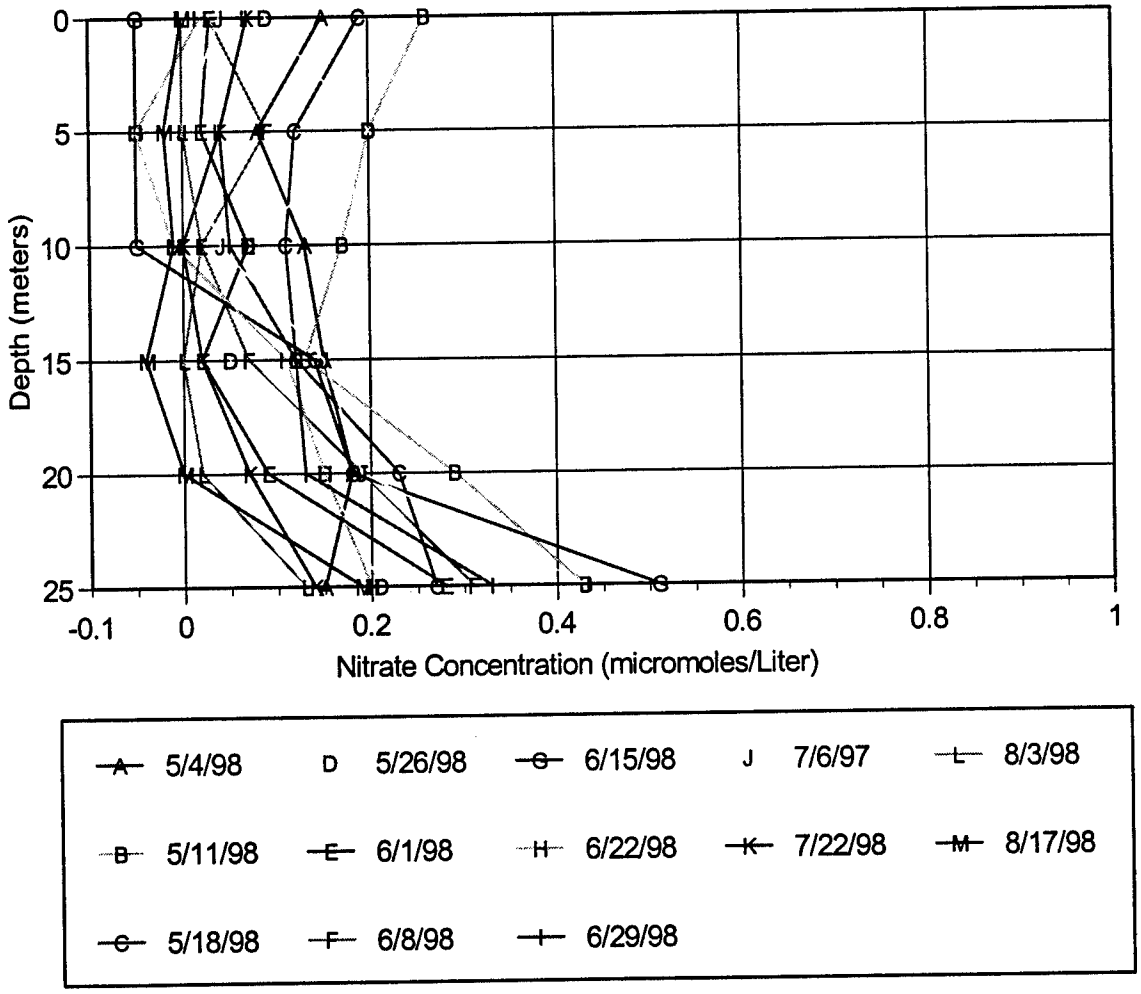

Figure 27

Nitrate Concentrations (*u*mol/L) – Site Dome

Depth	5/4/98	5/11/98	5/18/98	5/26/98	6/1/98	6/8/98	6/15/98	6/22/98	6/29/98	7/6/97	7/22/98	8/3/98	8/17/98
0	0.11	0.2	0.2	0.07	-0.02	0.14	N/A	0	0.03	0.05	0.08	0.12	0.16
5	0.18	0.18	0.12	0.09	0.08	0.08	N/A	0.01	0.03	0.05	-0.02	0.02	-0.03
10	0.14	0.29	0.1	0.08	-0.02	0.15	N/A	0.04	0.03	0.02	0.01	0.01	0.02
15	0.12	0.28	0.19	0.09	0.27	0.21	N/A	0.21	0.1	0.21	0.1	-0.01	0.03
20	0.21	0.37	0.26	0.19	0.04	0.29	N/A	0.29	0.37	0.39	0.32	0.27	0.15
25	0.35	0.55	0.33	0.31	0.28	0.43	N/A	0.46	0.42	0.42	0.19	0.4	0.45

Table 27

Dome Nitrate Concentration Profile

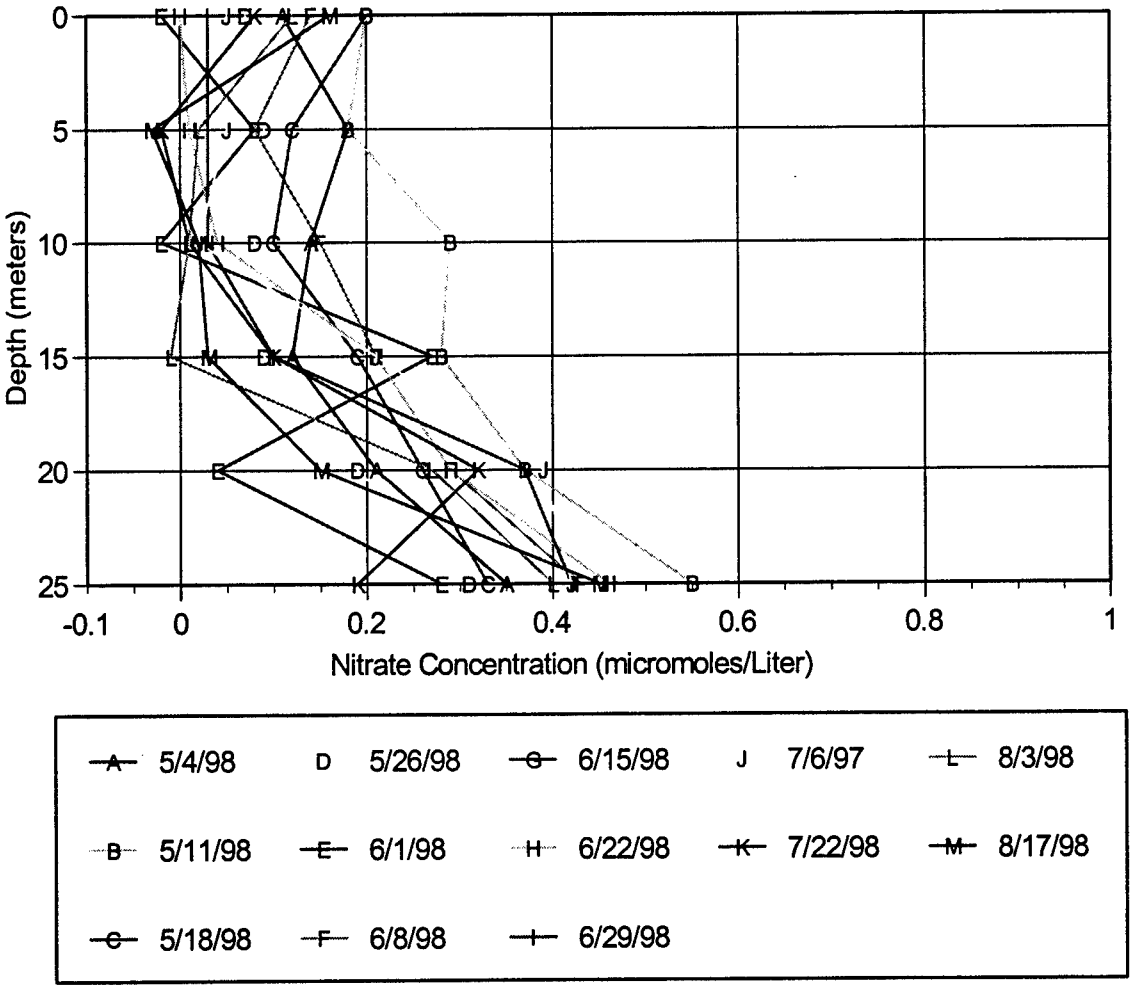

Figure 28

Phosphorus is also an important nutrient in the development and growth of microorganisms living in Lake George, but is normally found in much lower concentrations then nitrogen in freshwater systems. Phosphorus enters the water column from decomposition of organic material with subsequent run-off into the lake, but also becomes available from decomposition within the water column and release from the sediments. Like nitrogen, phosphorus is used in various roles in cell development such as manufacturing of nucleotides and amino acids.

Total phosphorus represents all of the phosphorus in the water column to include all organic and inorganic forms. This concentration is measured by converting all phosphorus in the sample to orthophosphate (PO_4^{3-}) and then measuring orthophosphate concentration as discussed in detail in the Methods and Materials.

The total phosphorus concentration in the water column remained fairly uniform throughout the entire summer sampling period, in the range of .01 to .05 micromoles per liter at both sites. The only aberration is the 25-meter sample from Site Dome on 22 July. This extremely high measurement was due to the contact of the sampling bottle with the sediment at 25 meters.

Total Phosphorus Concentrations (*u*mol/L) – Site Hague

Depth	5/4/98	5/11/98	5/18/98	5/26/98	6/1/98	6/8/98	6/15/98	6/22/98	6/29/98	7/6/97	7/22/98	8/3/98	8/17/98
0	0.019	0.018	0.011	0.011	0.052	0.04	0.016	0.009	0.015	0.008	0.008	0.007	0.008
5	0.025	0.019	0.03	0.014	0.063	0.027	0.014	0.012	0.015	0.012	0.012	0.005	0.01
10	0.023	0.022	0.025	0.014	0.064	0.03	0.015	0.015	0.027	0.008	0.008	0.006	0.011
15	0.031	0.025	0.015	0.022	0.066	0.043	0.021	0.018	0.015	0.015	0.015	0.01	0.018
20	0.028	0.021	0.012	0.019	0.07	0.035	0.016	0.028	0.015	0.01	0.01	0.019	0.022
25	0.03	0.02	0.015	0.023	0.075	0.025	0.029	0.024	0.012	0.01	0.01	0.012	0.035

Table 28

Hague Total Phosphorus Concentration Profile

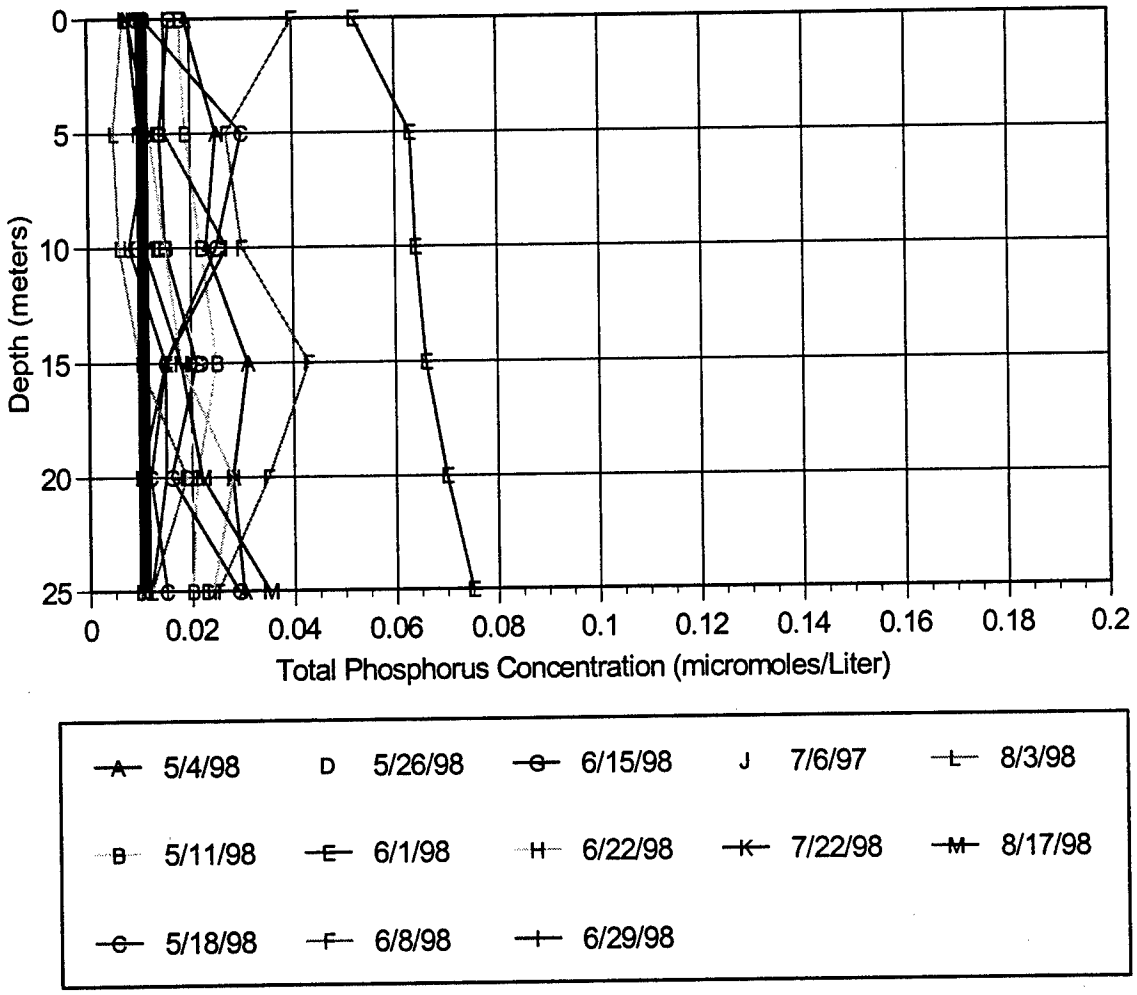

Figure 29

Total Phosphorus Concentrations (*u*mol/L) – Site Dome

Depth	5/4/98	5/11/98	5/18/98	5/26/98	6/1/98	6/8/98	6/15/98	6/22/98	6/29/98	7/6/97	7/22/98	8/3/98	8/17/98
0	0.018	0.016	0.012	0.011	0.019	0.028	0.009	0.012	0.009	0.017	0.011	0.007	0.011
5	0.039	0.022	0.02	0.012	0.014	0.035	0.009	0.017	0.011	0.016	0.008	0.009	0.015
10	0.037	0.022	0.038	0.017	0.023	0.027	0.012	0.021	0.012	0.032	0.019	0.013	0.025
15	0.03	0.035	0.028	N/A	0.032	0.052	0.033	0.043	0.011	0.022	0.015	0.011	0.02
20	0.026	0.025	0.019	0.028	0.04	0.024	0.031	0.026	0.017	0.031	0.012	0.014	0.018
25	0.023	0.018	0.02	0.018	0.025	0.018	0.017	0.024	0.015	0.02	0.161	0.012	0.02

Table 29

Dome Total Phosphorus Concentration Profile

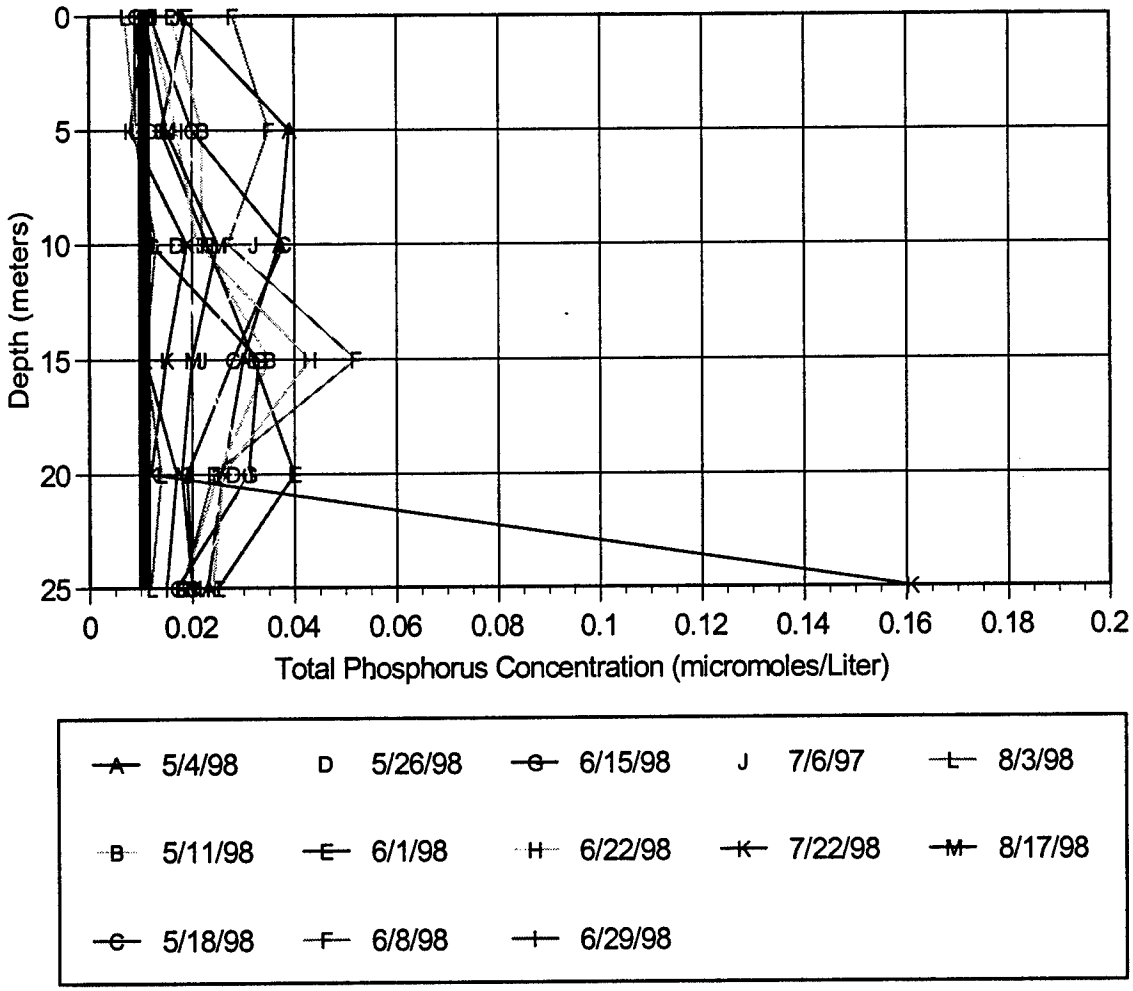

Figure 30

Dissolved phosphorus concentrations were the measure of phosphorus in a water sample that had previously been filtered through a 0.4-micron polycarbonate membrane filter. This filtering process removed most of the large organisms, however some picophytoplankton and bacteria are small enough to pass through this size filter. These samples would contain inorganic phosphorus along with free organic molecules or peptides.

Dissolved phosphorus measurements were in extremely low concentrations throughout the water column. Most measurements fall below the lowest standard used and are very close to the levels measured for experimental blanks. Because of these low levels some care should be exercised in their interpretation. These concentrations show no trends at either site, but do show that available phosphorus for use by microorganisms in Lake George is in very low supply.

Particulate phosphorus concentrations were determined by the difference in total phosphorus and dissolved phosphorus (**Particulate Phosphorus = Total Phosphorus – Dissolved Phosphorus**).

The only significant form of inorganic phosphorus in lakes is orthophosphate, PO_4^{3-} (Wetzel, 1975). The only measurable quantities in Lake George were found on the first two sampling dates (04 and 11 May 1998).

Dissolved Phosphorus Concentrations (*u*mol/L) – Site Hague

Depth	5/4/98	5/11/98	5/18/98	5/26/98	6/1/98	6/8/98	6/15/98	6/22/98	6/29/98	7/6/97	7/22/98	8/3/98	8/17/98
0	0	0.006	0.004	0.003	0.004	0.003	0.003	0.001	0.003	0.003	0.009	0.011	0.011
5	0.001	0.001	0.006	0.005	0.003	0.003	0.003	0.001	0.004	0.006	0.005	0.007	0.007
10	0.003	0.002	0.007	0.007	0.006	0.004	0.004	0.001	0.004	0.005	0.006	0.008	0.008
15	0.002	0.002	0.01	0.005	0.006	0.005	0.004	0	0.005	0.002	0.006	0.015	0.015
20	0	0	0.007	0.005	0.006	0.003	0.003	0.002	0.005	0.003	0.004	0.011	0.011
25	0.003	0	0.006	0.004	0.005	0.003	0.004	0.002	0.004	0.002	0.003	0.014	0.014

Table 30

Hague Dissolved Phosphorus Concentration Profile

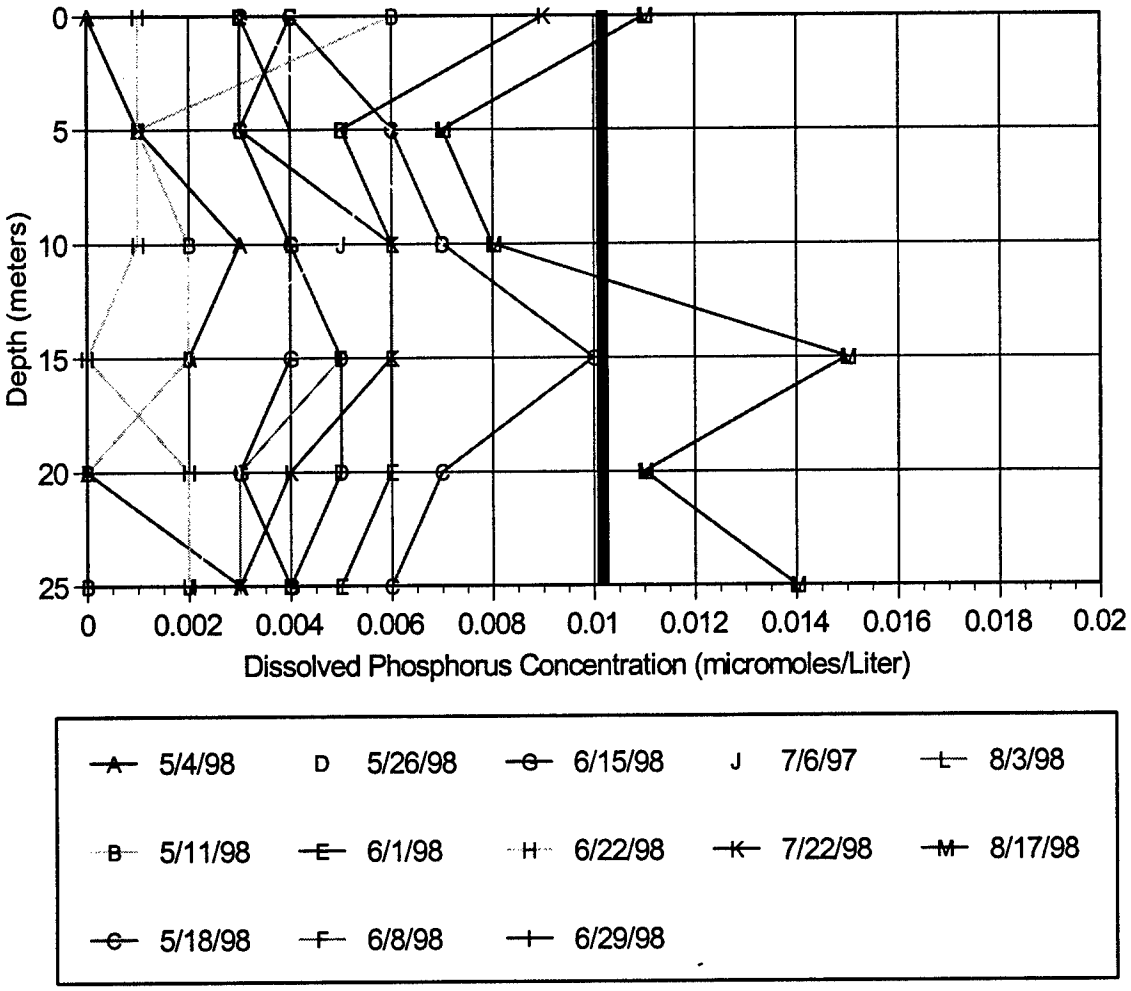

Figure 31

Dissolved Phosphorus Concentrations (*u*mol/L) – Site Dome

Depth	5/4/98	5/11/98	5/18/98	5/26/98	6/1/98	6/8/98	6/15/98	6/22/98	6/29/98	7/6/97	7/22/98	8/3/98	8/17/98
0	0.004	0.002	0.01	0.005	0.006	0.003	0.003	0.002	0.005	0.003	0.004	0.01	0.01
5	0.007	0.007	0.009	0.005	0.005	0.003	0.003	0.003	0.005	0.004	0.002	0.012	0.012
10	0.004	0.006	0.01	0.006	0.006	0.004	0.003	0.002	0.006	0.006	0.009	0.013	0.013
15	0.002	0.006	0	0.007	0.005	0.004	0.004	0.002	0.007	0.005	0.01	0.017	0.017
20	0.006	0.004	0.01	0.007	0.006	0.004	0.005	0.002	0.006	0.004	0.01	0.015	0.015
25	0.002	0.003	0.011	0.005	0.006	0.004	0.005	0.002	0.005	0.006	0.008	0.015	0.015

Table 31

Dome Dissolved Phosphorus Concentration Profile

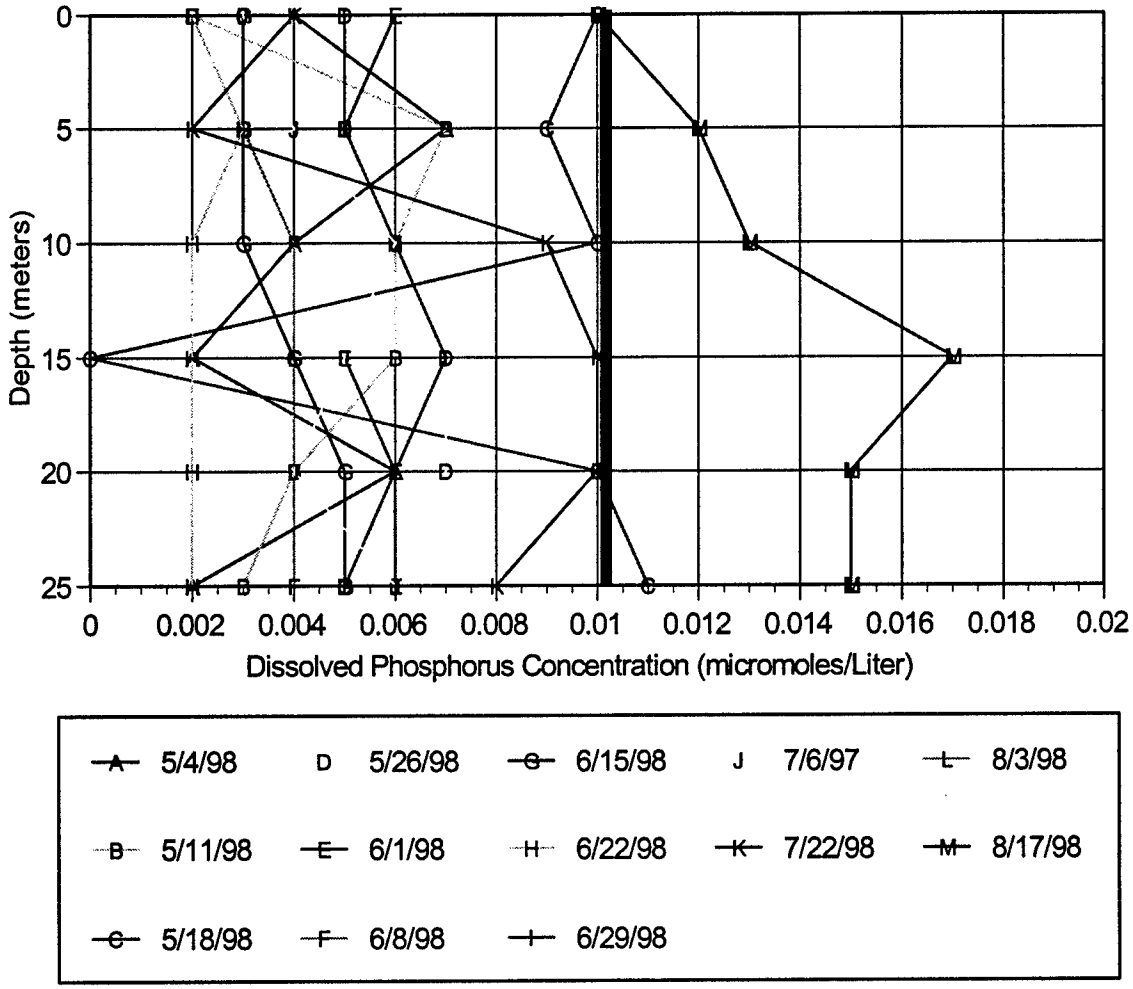

Figure 32

Particulate Phosphorus Concentrations (*u*mol/L) – Site Hague

Depth	5/4/98	5/11/98	5/18/98	5/26/98	6/1/98	6/8/98	6/15/98	6/22/98	6/29/98	7/6/97	7/22/98	8/3/98	8/17/98
0	0.019	0.012	0.007	0.008	0.048	0.037	0.013	0.008	0.012	0.005	-0.001	-0.004	-0.003
5	0.024	0.018	0.024	0.009	0.06	0.024	0.011	0.011	0.011	0.006	0.007	-0.002	0.003
10	0.02	0.02	0.018	0.007	0.058	0.026	0.011	0.014	0.023	0.003	0.002	-0.002	0.003
15	0.029	0.023	0.005	0.017	0.06	0.038	0.017	0.018	0.01	0.013	0.009	-0.005	0.003
20	0.028	0.021	0.005	0.014	0.064	0.032	0.013	0.026	0.01	0.007	0.006	0.008	0.011
25	0.027	0.02	0.009	0.019	0.07	0.022	0.025	0.022	0.008	0.008	0.007	-0.002	0.021

Table 32

Hague Particulate Phosphorus Concentration Profile

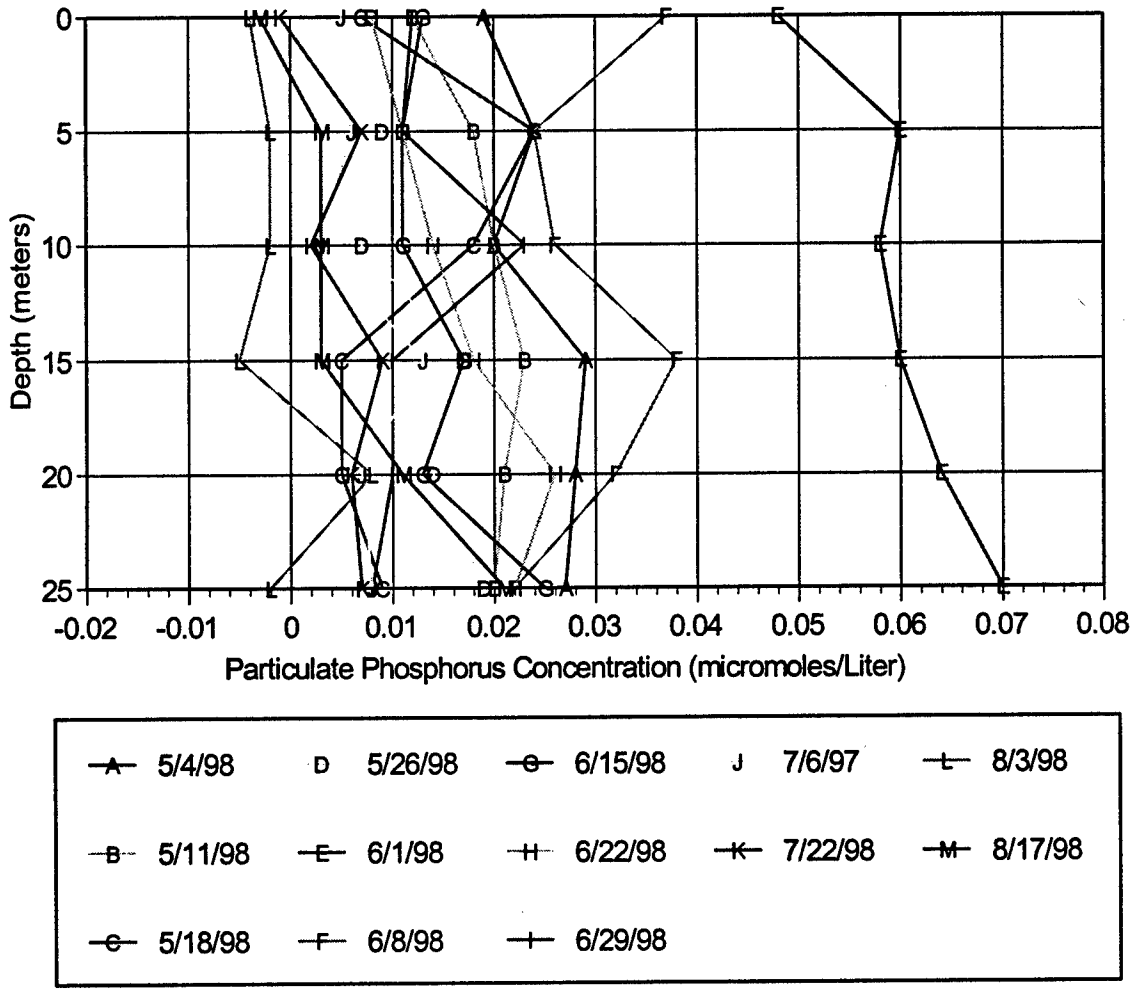

Figure 33

Particulate Phosphorus Concentrations (*u*mol/L) – Site Dome

Depth	5/4/98	5/11/98	5/18/98	5/26/98	6/1/98	6/8/98	6/15/98	6/22/98	6/29/98	7/6/97	7/22/98	8/3/98	8/17/98
0	0.014	0.014	0.002	0.006	0.013	0.025	0.006	0.01	0.004	0.014	0.007	-0.003	0.001
5	0.032	0.015	0.011	0.007	0.009	0.032	0.006	0.014	0.006	0.012	0.006	-0.003	0.003
10	0.033	0.016	0.028	0.011	0.017	0.023	0.009	0.019	0.006	0.026	0.01	0	0.012
15	0.028	0.029	0.028	N/A!	0.027	0.048	0.029	0.041	0.004	0.017	0.005	-0.006	0.003
20	0.02	0.021	0.009	0.021	0.034	0.02	0.026	0.024	0.011	0.027	0.002	-0.001	0.003
25	0.021	0.015	0.009	0.013	0.019	0.014	0.012	0.022	0.01	0.014	0.153	-0.003	0.005

Table 33

Dome Particulate Phosphorus Concentration Profile

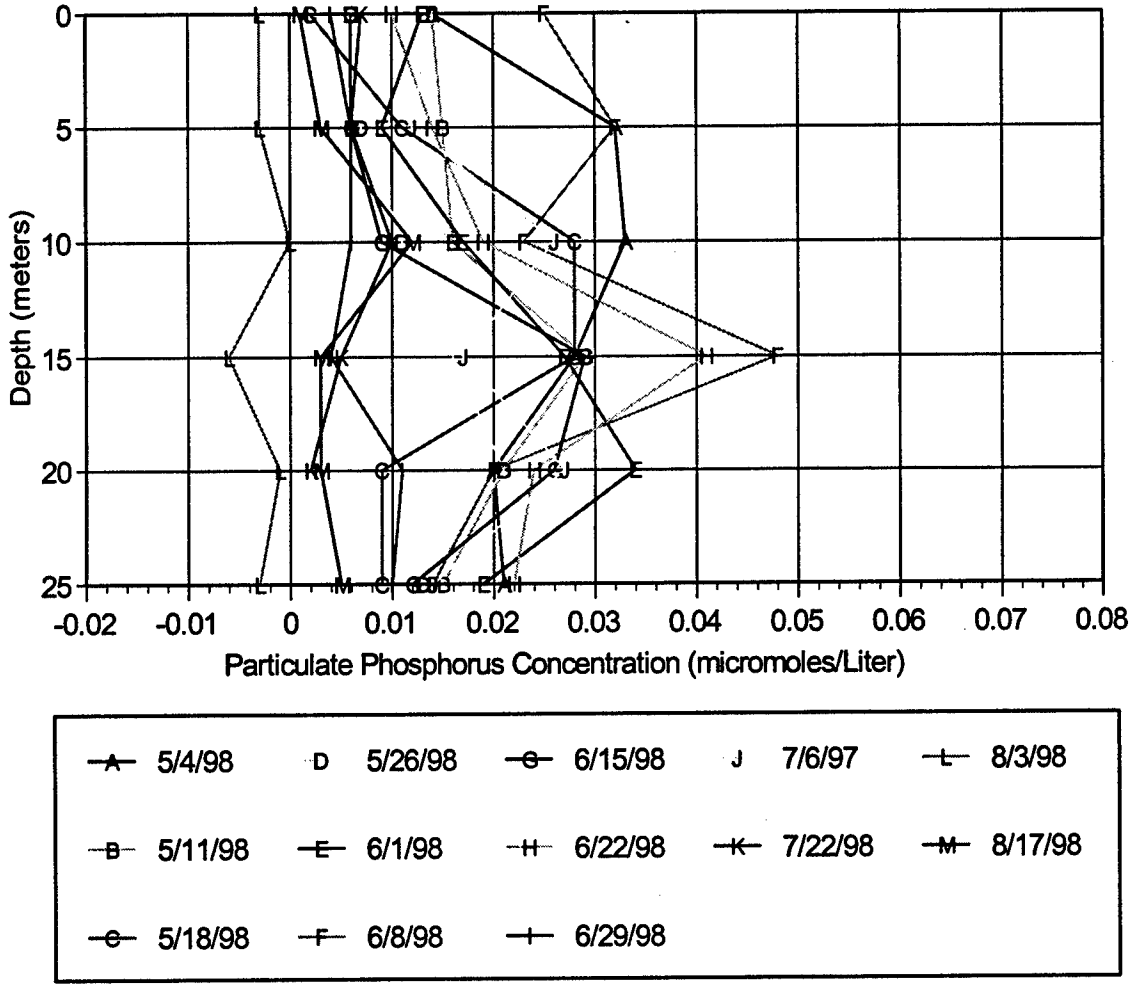

Figure 34

Orthophosphate Concentrations (*u*mol/L) – Site Hague

Depth	5/4/98	5/11/98	5/18/98	5/26/98	6/1/98	6/8/98	6/15/98	6/22/98	6/29/98	7/6/97	7/22/98	8/3/98	8/17/98
0	0.03	0.02											
5	0.03	0.02	0	0	0	0	0	0	0	0	0	0	0
10	0.03	0.01											
15	0.03	0.01	0	0	0	0	0	0	0	0	0	0	0
20	0.03	0											
25	0.04	0.01	0	0	0	0	0	0	0	0	0	0	0

Table 34

Hague Orthophosphate Concentration Profile

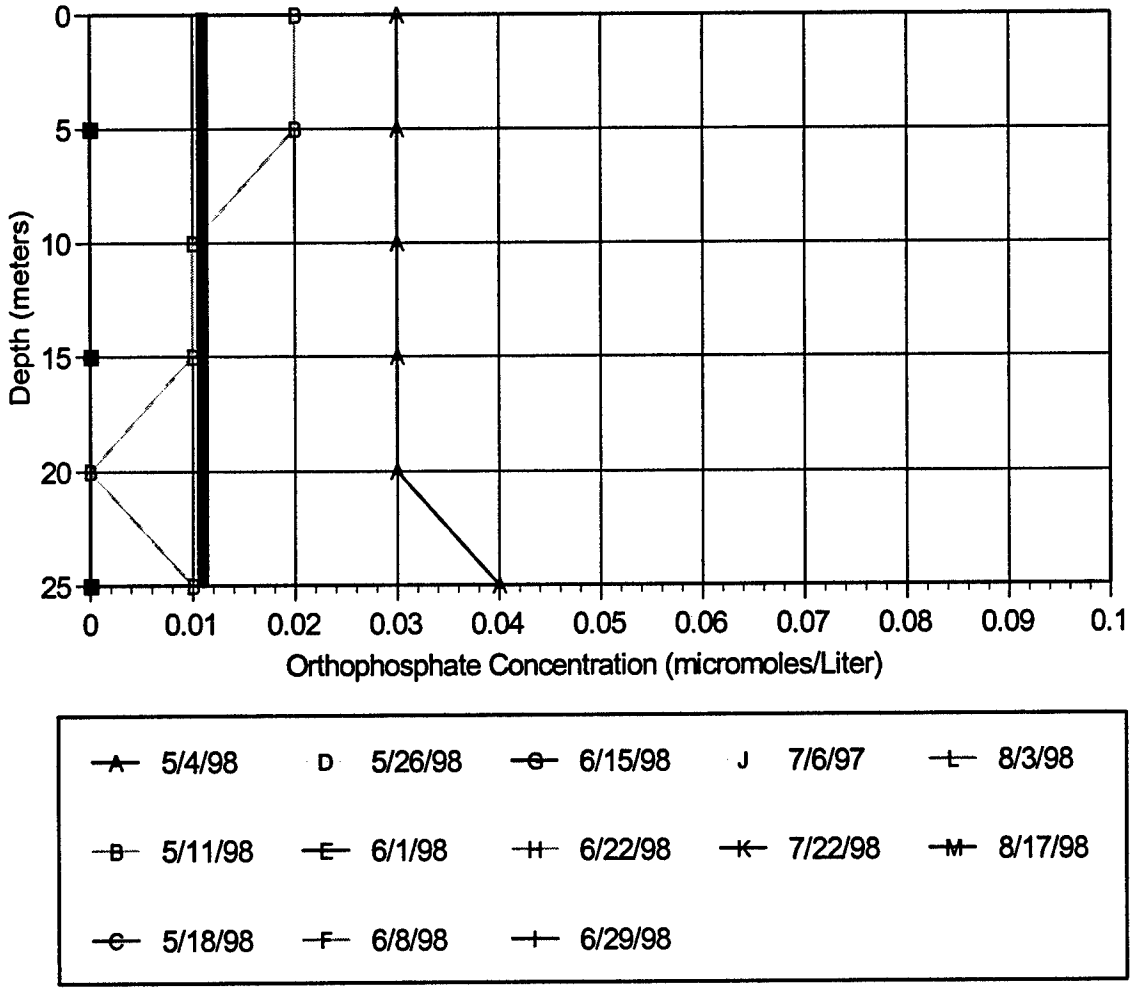

Figure 35

Orthophosphate Concentrations (*u*mol/L) – Site Dome

Depth	5/4/98	5/11/98	5/18/98	5/26/98	6/1/98	6/8/98	6/15/98	6/22/98	6/29/98	7/6/97	7/22/98	8/3/98	8/17/98
0	0.03	0.01	0										
5	0.04	0.01	0	0	0	0	0	0	0	0	0	0	0
10	0.06	0	0										
15	0.06	0.01	0	0	0	0	0	0	0	0	0	0	0
20	0.07	0.01	0										
25	0.08	0.01	0	0	0	0	0	0	0	0	0	0	0

Table 35

Dome Orthophosphate Concentration Profile

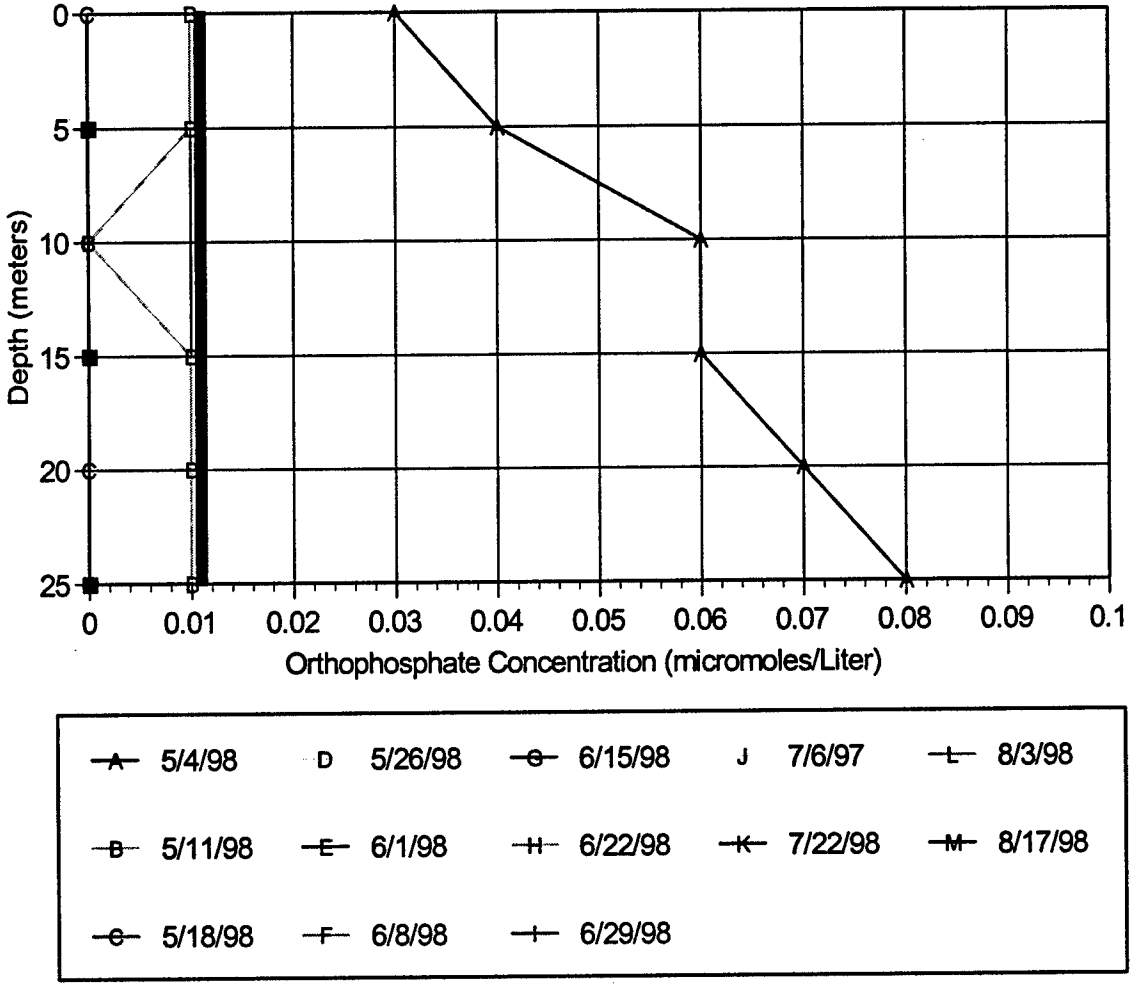

Figure 36

Chlorophyll a is the principal pigment involved in photosynthesis by plants and phytoplankton. It is used frequently to measure the productivity in lakes and oceans. Phaeophytin is a chlorophyll a molecule that has lost its magnesium. Both of these pigments affect the amount and wavelength of light that can penetrate into the water column.

In Lake George a chlorophyll a maximum was found at or near the bottom of the metalimnion on most sampling dates. A second maximum was seen at Site Dome on 11 May at 5 meters. This area at or just below the metalimnion is usually high in nutrients when compared to the rest of the water column and sufficient light reaches this level to provide the energy necessary to drive photosynthesis. The two sites did differ in chlorophyll a and phaeophytin concentrations with the greater concentrations found at Site Dome in the south basin.

Chlorophyll a Concentrations (*u*gs/L) – Site Hague

Depth	5/4/98	5/11/98	5/18/98	5/26/98	6/1/98	6/8/98	6/15/98	6/22/98	6/29/98	7/6/97	7/22/98	8/3/98	8/17/98
0	0.25	0.422	0.46	0.45	0.83	0.8	1.51	0.87	0.831	0.71	0.86	1.08	1.04
5	1.18	1.98	0.58	0.83	0.88	1.22	1.52	0.88	0.776	0.78	1	1.15	1.08
10	1.51	2.53	0.6	1.13	1.08	1.27	1.54	1.06	1.2	1.83	1.13	1.15	1.04
15	1.21	2.02	1.31	1.88	1.57	1.36	1.02	1.08	1.24	1.81	1.12	1.68	2.95
20	1.6	2.69	1.28	1.91	1.66	1.86	1.74	1.24	0.981	1.45	1.31	1.15	1.42
25	1.14	1.92	1.18	1.18	1.05	1.54	1.23	1.9	1.53	1.31	1.2	0.85	0.64

Table 36

Hague Chlorophyll a Concentration Profile

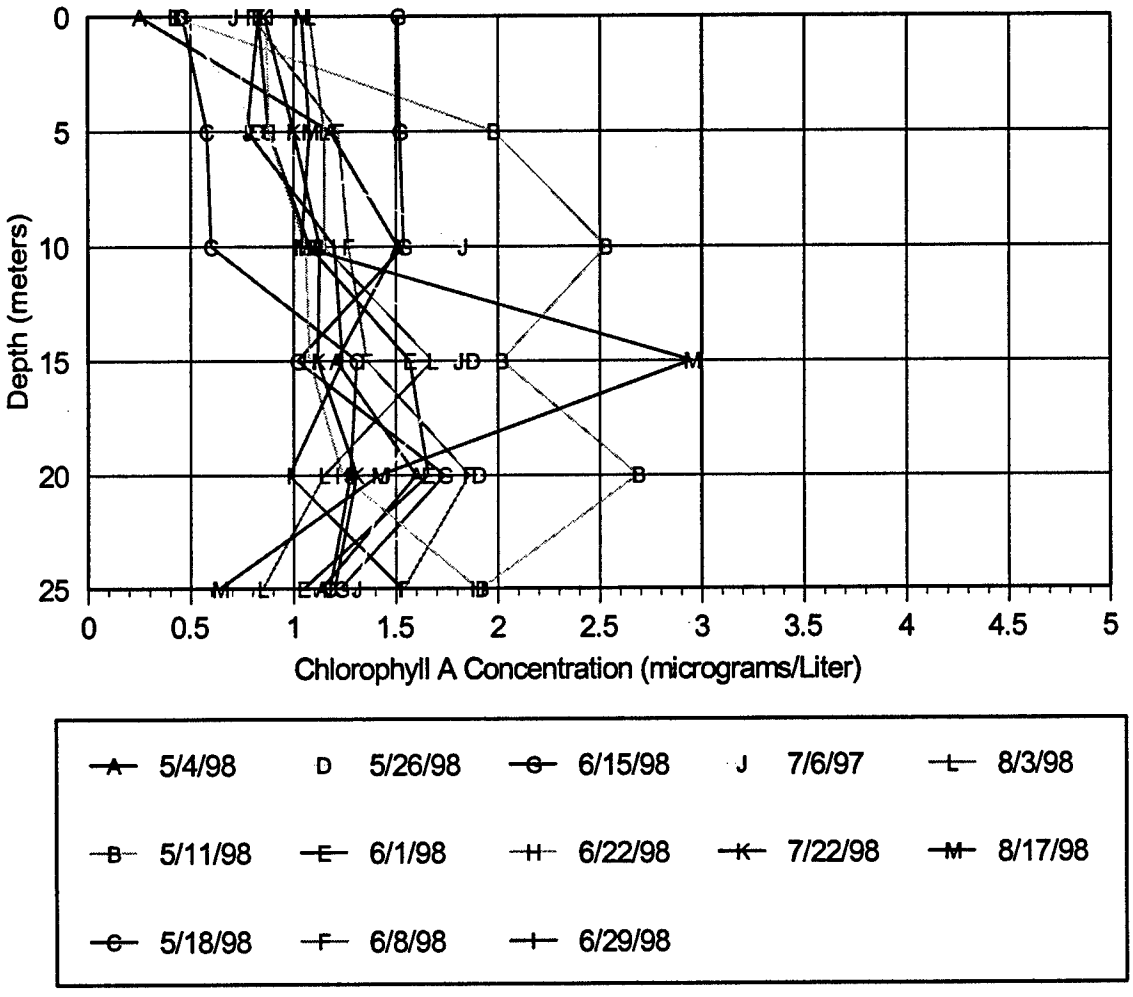

Figure 37

Chlorophyll a Concentrations (*u*gs/L) – Site Dome

Depth	5/4/98	5/11/98	5/18/98	5/26/98	6/1/98	6/8/98	6/15/98	6/22/98	6/29/98	7/6/97	7/22/98	8/3/98	8/17/98
0	0.78	1.31	0.37	0.79	1.19	0.92	1.04	0.84	0.699	1	1.07	0.88	1.35
5	2.5	4.19	0.86	0.89	1.23	1.34	0.91	0.94	0.931	1.59	1.26	1.18	1.49
10	2.38	3.99	1.22	1.29	1.5	1.62	1.38	1.09	1.27	3.16	2.73	2.89	2.08
15	2.52	4.22	1.64	1.81	1.58	1.92	1.51	1.25	0.709	1.02	1.8	3.31	4.48
20	2.19	3.67	1.91	1.96	0.94	2.3	2.46	1.18	0.875	1.36	1.39	1.42	3.47
25	2.03	3.4	1.75	1.7	1.01	1.82	1.69	1.1	0.99	1.17	2.5	0.67	1

Table 37

Dome Chlorophyll a Concentration Profile

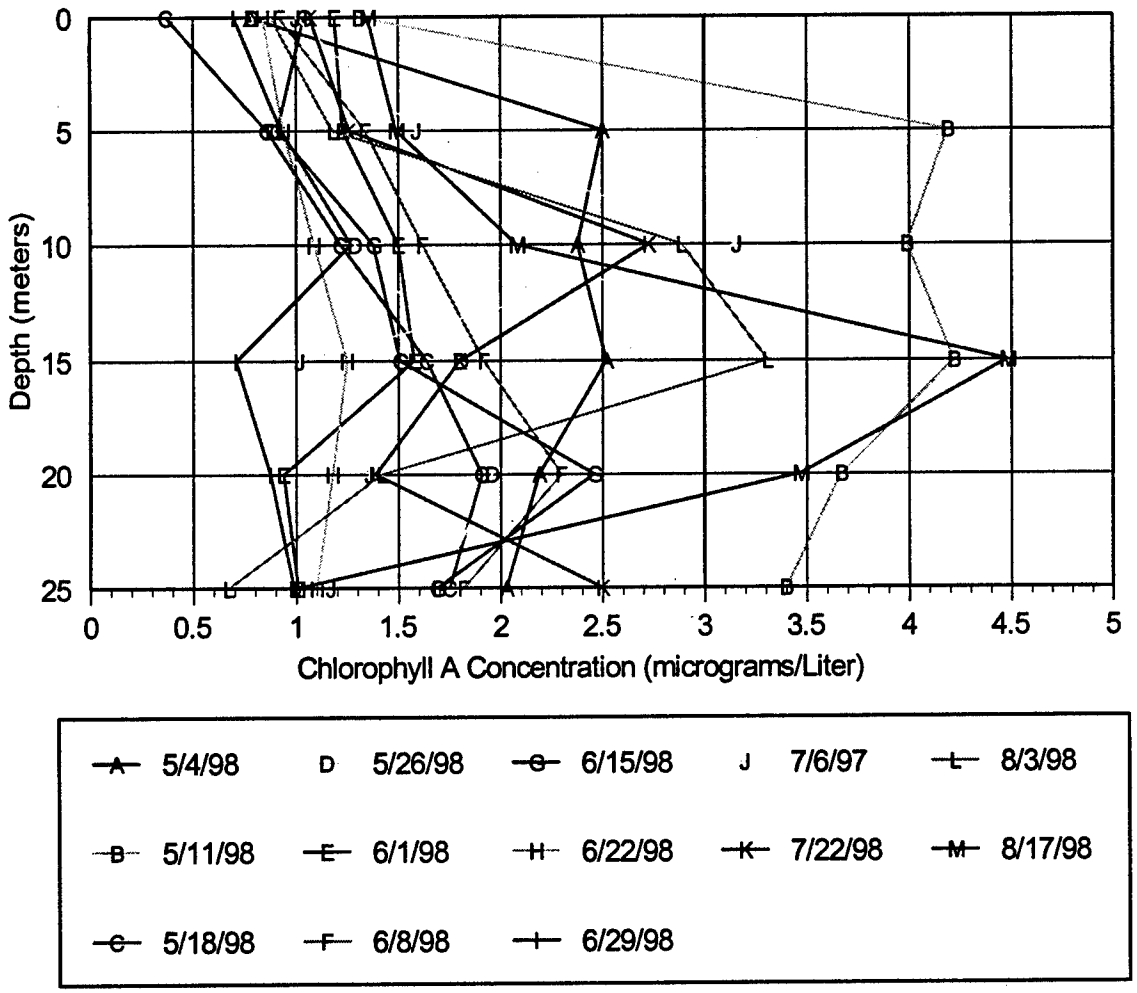

Figure 38

Phaeophytin Concentrations (*u*gs/L) – Site Hague

Depth	5/4/98	5/11/98	5/18/98	5/26/98	6/1/98	6/8/98	6/15/98	6/22/98	6/29/98	7/6/97	7/22/98	8/3/98	8/17/98
0	0.3	0.43	0.09	0.06	0.5	0.3	0.58	0.32	0.543	0.2	0.33	0.32	0.19
5	1.31	1.84	0.25	0.12	0.56	0.52	0.74	0.5	0.765	0.48	0.42	0.3	0.26
10	1.13	1.52	0.35	0.15	0.58	0.61	1.05	0.63	1.27	0.25	0.44	0.38	0.3
15	1.49	2.12	0.8	0.08	0.85	0.78	1.51	0.62	1.08	0.16	0.43	0.61	0.69
20	1.1	1.46	0.84	0.31	1.07	1.01	1.5	0.87	0.973	0.17	0.66	0.52	0.62
25	1.02	1.4	0.78	0.45	1.03	0.94	1.03	1.34	1.32	0.29	0.56	0.4	0.35

Table 38

Hague Phaeophytin Concentration Profile

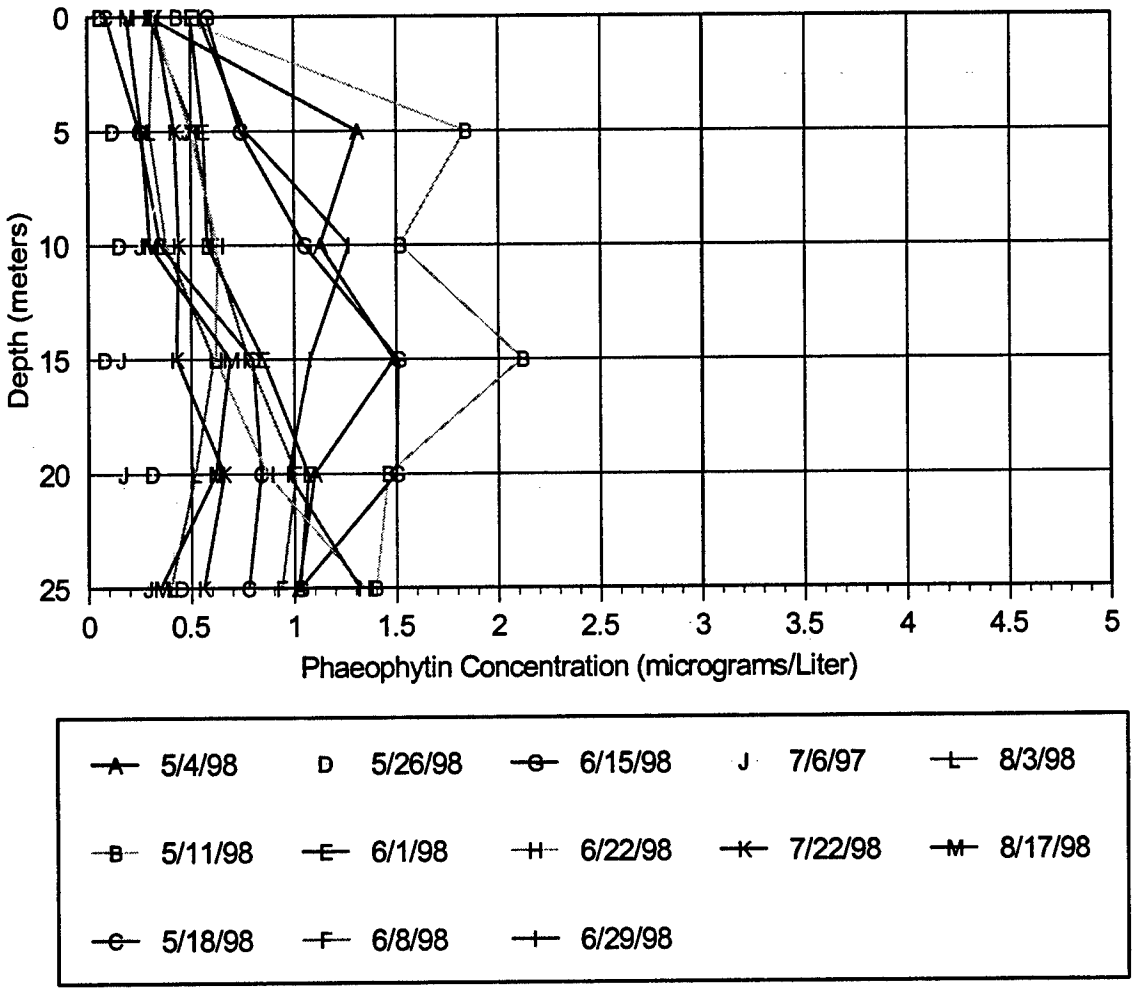

Figure 39

Phaeophytin Concentrations (*u*gs/L) – Site Dome

Depth	5/4/98	5/11/98	5/18/98	5/26/98	6/1/98	6/8/98	6/15/98	6/22/98	6/29/98	7/6/97	7/22/98	8/3/98	8/17/98
0	0.58	0.77	0.25	0.09	0.68	0.73	0.84	0.62	1.25	0.14	0.43	0.31	0.48
5	1.12	1.36	0.46	0.16	0.73	0.92	1.24	0.72	1.21	0.21	0.44	0.31	0.4
10	2.09	2.86	0.75	0.21	0.96	1.58	0.95	0.79	1.8	0.3	1.09	0.89	0.83
15	1.62	2.12	0.98	0.48	1.65	1.75	2.78	1.56	2.31	0.87	1.39	1.03	1.49
20	1.29	1.66	0.99	0.48	2.25	1.82	1.5	1.47	1.92	0.42	0.77	0.74	0.77
25	1.32	1.73	1.37	0.54	2.08	1.91	2.09	1.42	1.61	0.48	4.93	0.47	0.69

Table 39

Dome Phaeophytin Concentration Profile

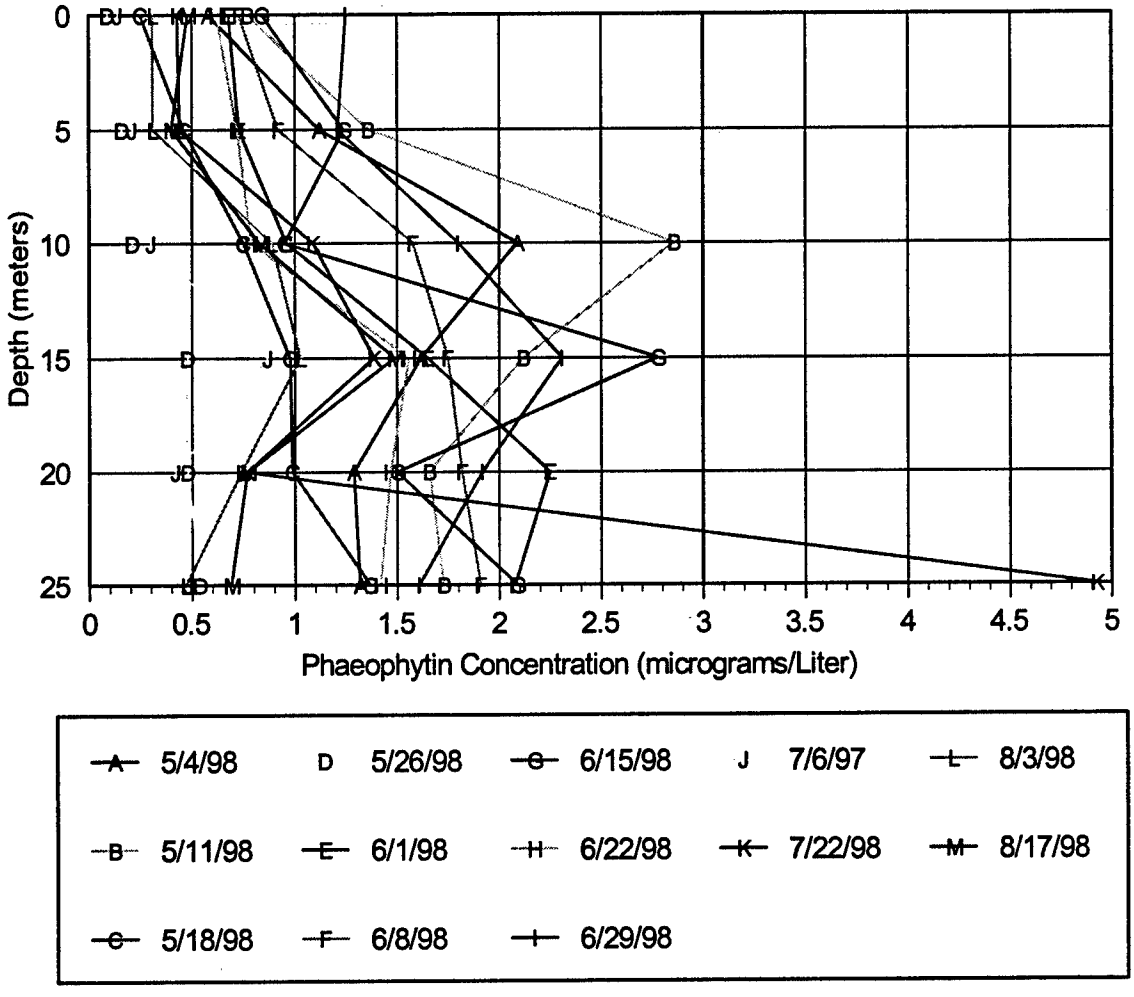

Figure 40

Cyanobacteria population profiles are discussed in detail in the following section, Discussion and Conclusions.

Cyanobacteria Populations - *Synechococcus* (cells/ml) – Site Hague

Depth	5/4/98	5/11/98	5/18/98	5/26/98	6/1/98	6/8/98	6/15/98	6/22/98	6/29/98	7/6/97	7/22/98	8/3/98	8/17/98
0	642	267	360	189	221	153	217	182	528	1087	2770	3939	3640
5	485	367	317	264	378	135	175	242	663	1319	2734	4103	3918
10	535	510	389	271	228	189	242	1137	2549	3266	2827	3091	4150
15	838	667	570	317	435	1159	1832	2834	3483	4250	4624	4930	5077
20	1105	1087	1408	1226	1679	2057	1733	2902	2595	3387	6200	7355	4863
25	881	1312	1783	2360	2638	1636	1234	2339	2075	1469	5091	6018	3362

Table 40
Hague *Synechococcus* Population Profile

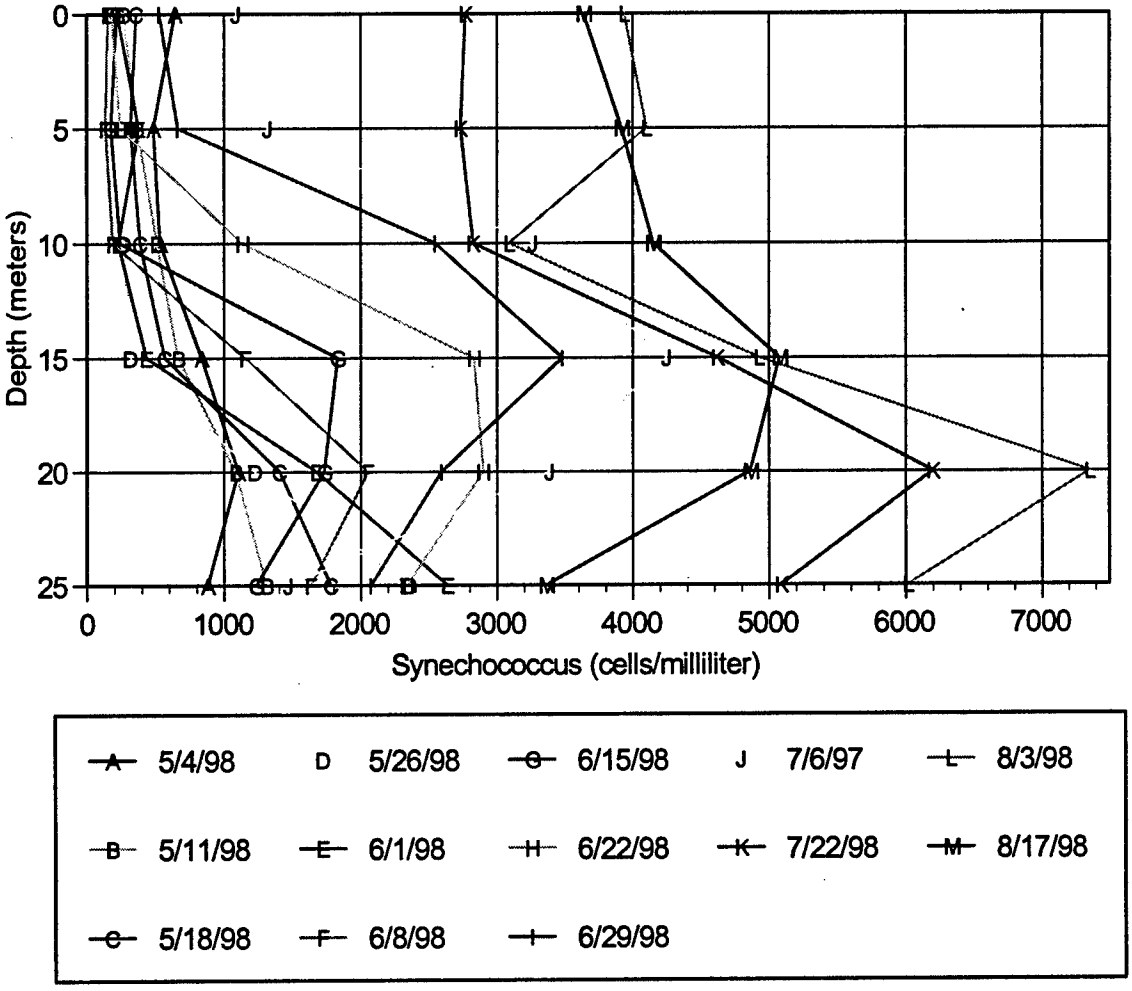

Figure 41

Cyanobacteria Populations - *Synechococcus* (cells/ml) – Site Dome

Depth	5/4/98	5/11/98	5/18/98	5/26/98	6/1/98	6/8/98	6/15/98	6/22/98	6/29/98	7/6/97	7/22/98	8/3/98	8/17/98
0	670	553	260	164	353	492	720	403	1152	2217	3180	3394	3308
5	567	706	260	225	342	560	781	602	1234	4385	4278	4863	4349
10	799	784	674	524	517	895	870	1690	2977	5123	6439	5961	2838
15	1062	1405	998	920	1266	1209	1387	1547	4139	3636	5579	6043	4948
20	930	1084	1326	1070	1048	1037	845	923	1558	2285	4235	5109	4360
25	602	895	1305	941	984	777	781	353	916	1854	N/A	2250	2061

Table 41

Dome *Synechococcus* Population Profile

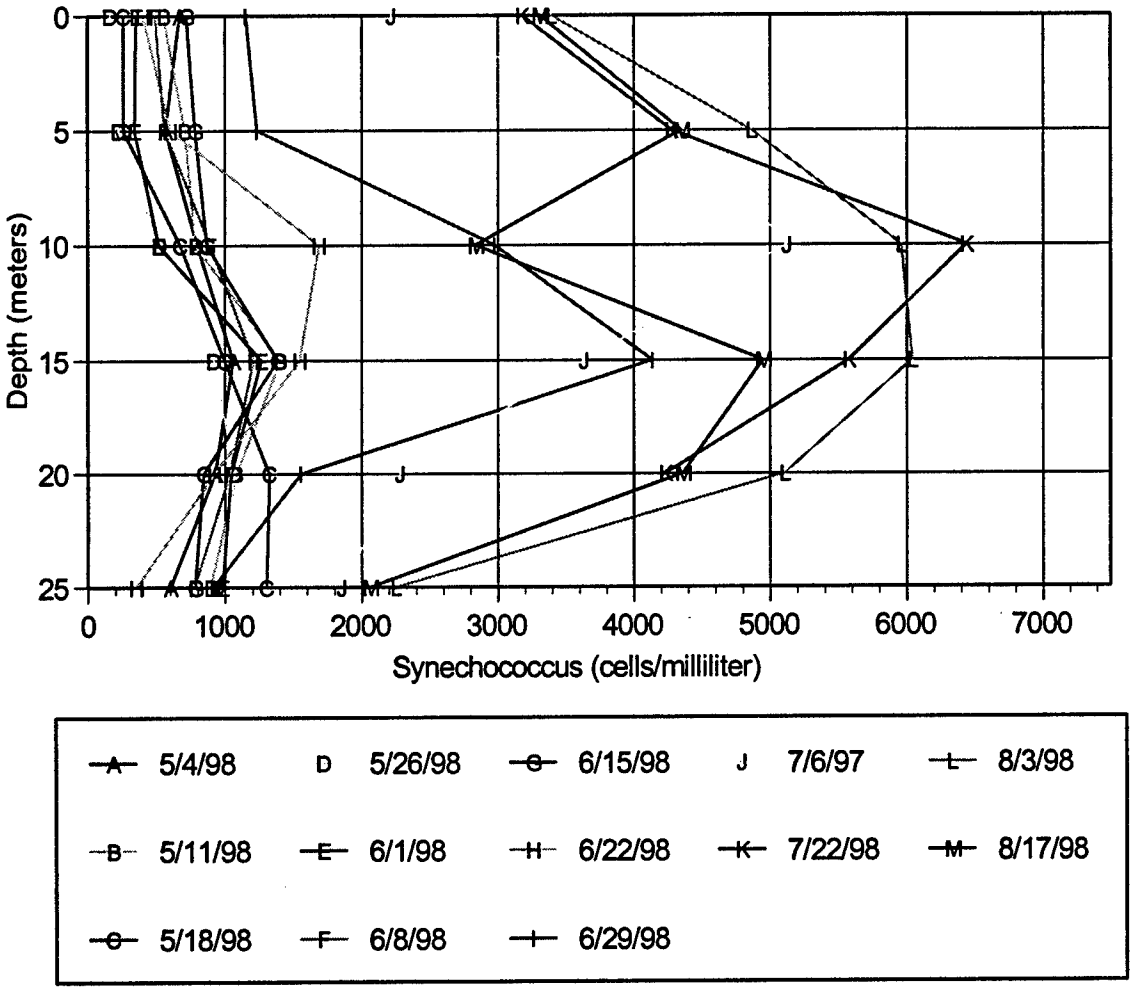

Figure 42

DISCUSSION AND CONCLUSIONS

The principle type of cyanobacteria found in Lake George, New York is small (.5 - 2 microns), phycoerythrin containing forms morphologically identified as belonging to the genus *Synechococcus*. These organisms represent over 90% of all the cyanobacteria enumerated for the samples collected in the summer of 1998, as well as the samples collected during the summer 1997 (Appendix A). Although there were other forms of Cyanobacteria detected in the water samples, including filamentous along with some phycocyanin containing forms, these did not appear in enough frequency to be useful in any type of analysis. For this reason from this point forward whenever the term cyanobacteria is used, it will refer to the more numerous small phycoerythrin containing *Synechococcus*.

The data collected was investigated using several different methods. First the data was examined in effort to find any general trends or patterns in the *Synechococcus* population at Site Dome and Site Hague. We also looked for general trends in the chemical and physical data in an effort to better understand how these factors were changing throughout the duration of the sampling period. Patterns or trends in this physical and chemical data helped to better understand the dynamics associated with the population distribution of the *Synechococcus* in Lake George, New York.

Secondly a series of simple linear regressions were used to determine if there were any direct correlations between a single measured chemical or physical variable and the size of the corresponding *Synechococcus* population.

Each variable was individually compared to the corresponding *Synechococcus* population using Microsoft Excel Spreadsheet Chart Functions.

The third approach taken, with the assistance of a mathematics graduate student, was to conduct a multiple linear regression analysis of all the variables using the statistical program known as Statistical Analysis Software System (SAS). Using this analysis a series of mathematical models were developed to determine the relationships between all the measured variables and the *Synechococcus* population at Site Hague and Site Dome.

In general terms the data show that there are slight differences between the water clarity in the north basin (Site Hague) and the south basin (Site Dome). The Secchi Disk Depths, which are a measure of water clarity, are on average ≃ two meters deeper at Site Hague in the northern basin then at Site Dome in the southern basin (see Figure 2). The two sites do have similar seasonal Secchi Disk progression patterns during this sampling period, however the lake was always clearer at the northern site than at the southern site (see Figure 2). This is not the direct result of only the increased *Synechococcus* populations throughout the sampling period, but also due to increases in eukaryotic phytoplankton and organic detritus.

Differences were also noted in the seasonal and vertical patterns of the *Synechococcus* at each site. In the late spring and early summer at Site Hague the greatest populations of Synechococcus were found in the deep-water samples, 20 and 25 meters. Figure 43 shows that this trend continued at Site Hague until mid-Jun at which time the population began to increase in the 15-

meter samples. By 06 July 1998 the Synechococcus maximum had moved up in the water column to the nutrient rich water just below the metalimnion. With only two exceptions on 22 July and 03 August this pattern would remain the same throughout the monitoring period. This pattern was not the case at Site Dome. The Synechococcus maximum was always at or adjacent to the 15 meter sampling depth (see Figure 44) from the beginning of the sampling period on 04 May 1998 to the end of the monitoring period on 17 August 1998.

Hague Seasonal *Synechococcus* Profile

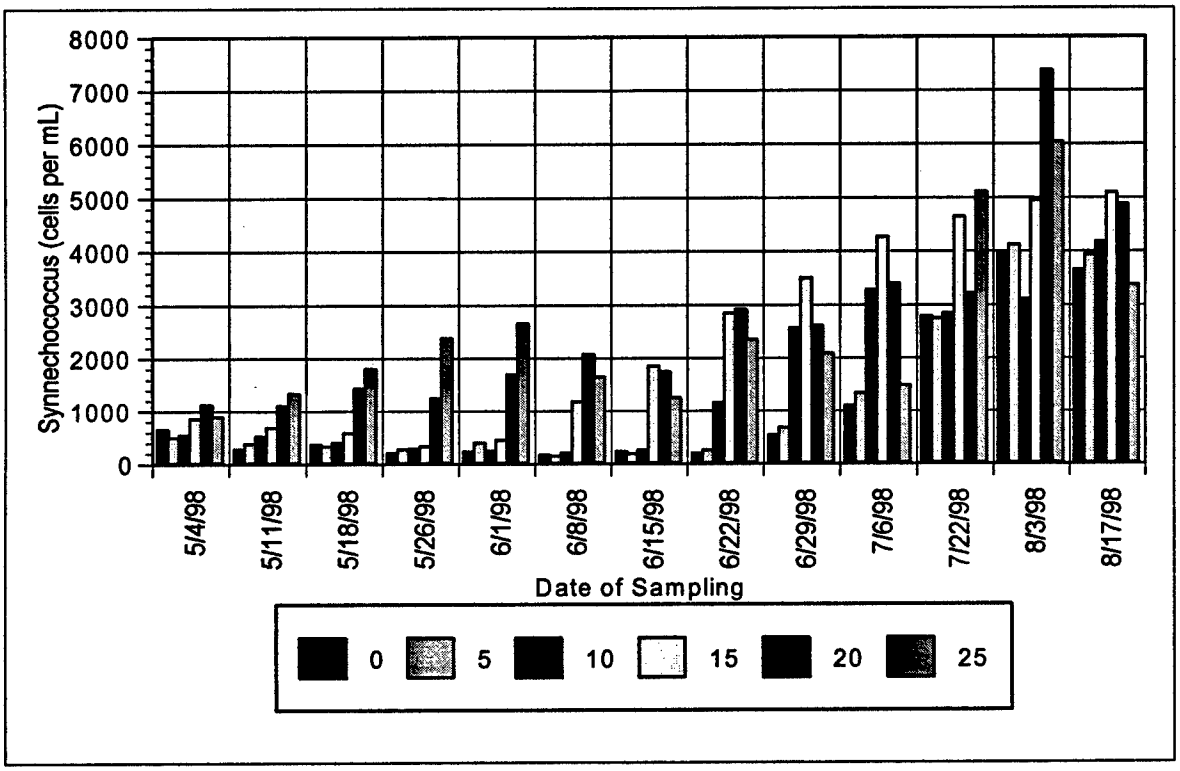

Figure 43

Dome Seasonal *Synechococcus* Profile

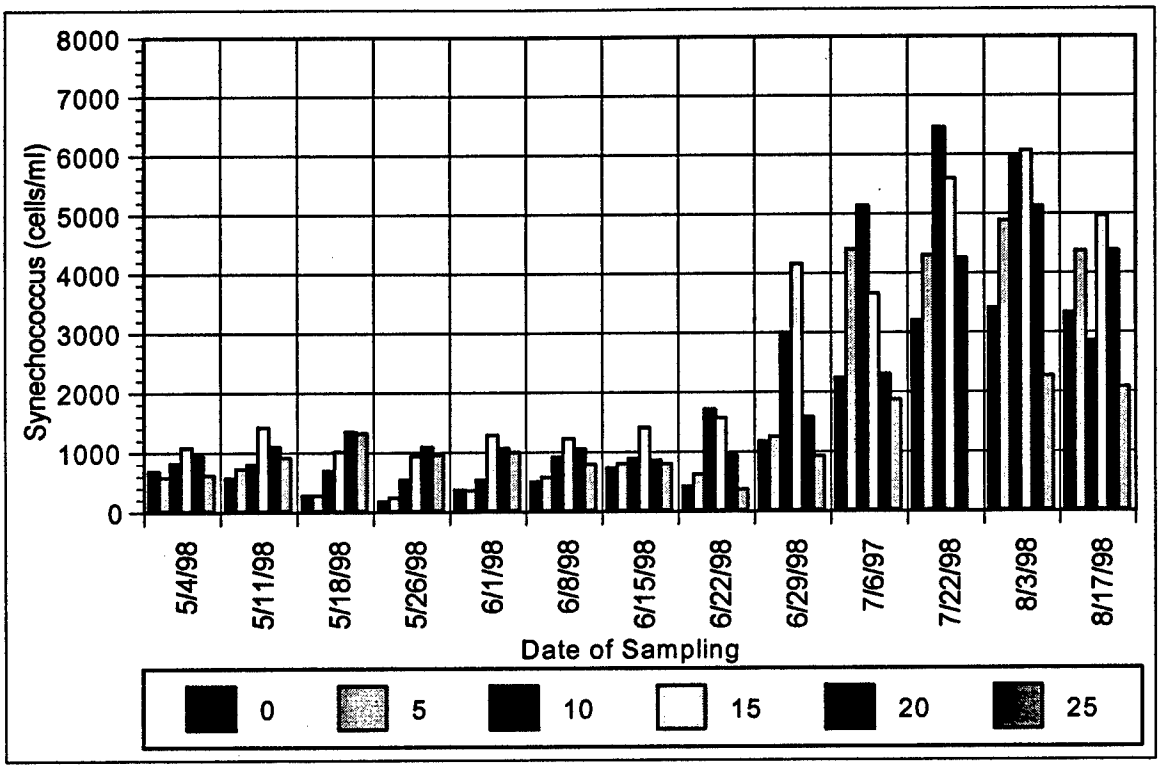

Figure 44

Both sites were similar in their progressive increase in *Synechococcus* populations throughout the season and both sites reached their maximum total populations on the 03 August 1998 sampling date. This pattern of rapid increase in population after mid-June reaching a maximum in early August was also found to occur in Lake Ontario (Caron et al, 1982). The *Synechococcus* populations at both sites were found to have declined after this on the subsequent sampling date, 17 August 1998. This same pattern of reaching a maximum population in early August was also seen in the data from the summer 1997 monitoring program (Appendix A).

The greatest populations of *Synechococcus* were found to occur in the water column at depths where they received between approximately 1-2% of the surface sunlight. This light level usually corresponded to the depths in the vicinity of 20 meters. This same pattern of a cyanobacterial maximum has been found to occur in marine environments (Murphy & Haugen, 1985). Figures 45, 46, 47 and 48 show that this pattern was the same for both sites at the beginning and the end of the study period.

Hague 04 May *Synechococcus* & Percent Illumination Profile

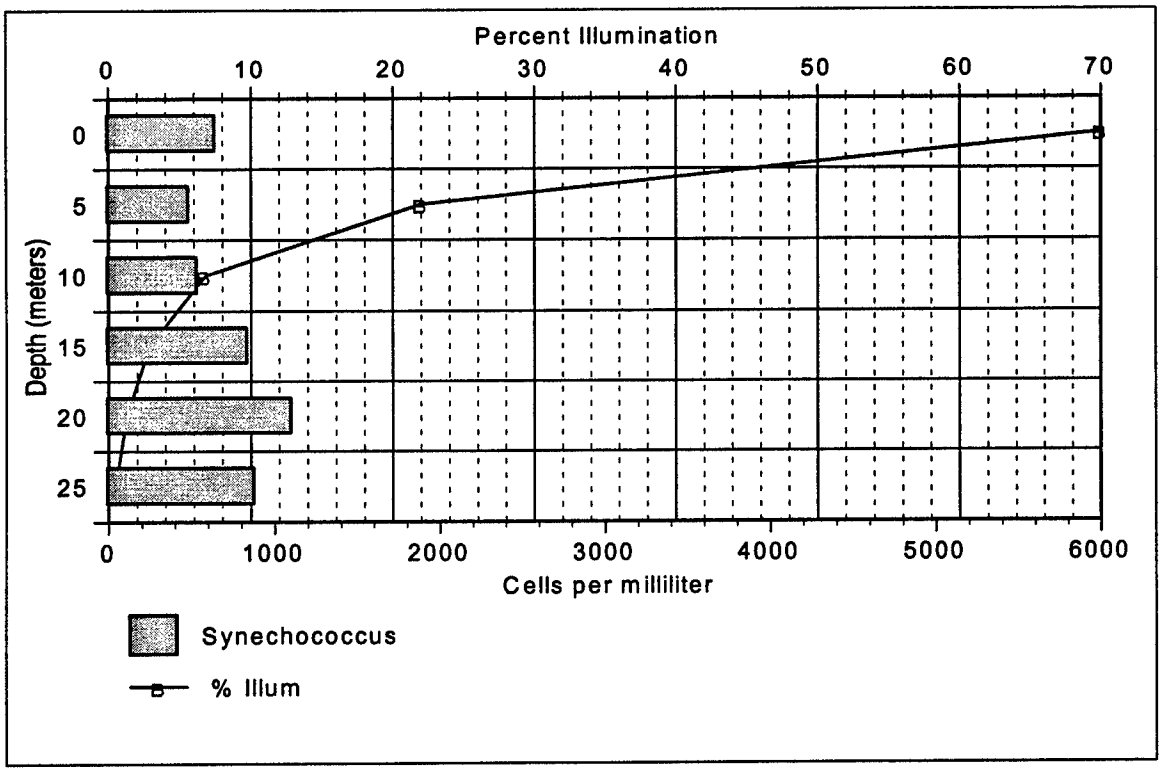

Figure 45

Hague 17 Aug *Synechococcus* & Percent Illumination Profile

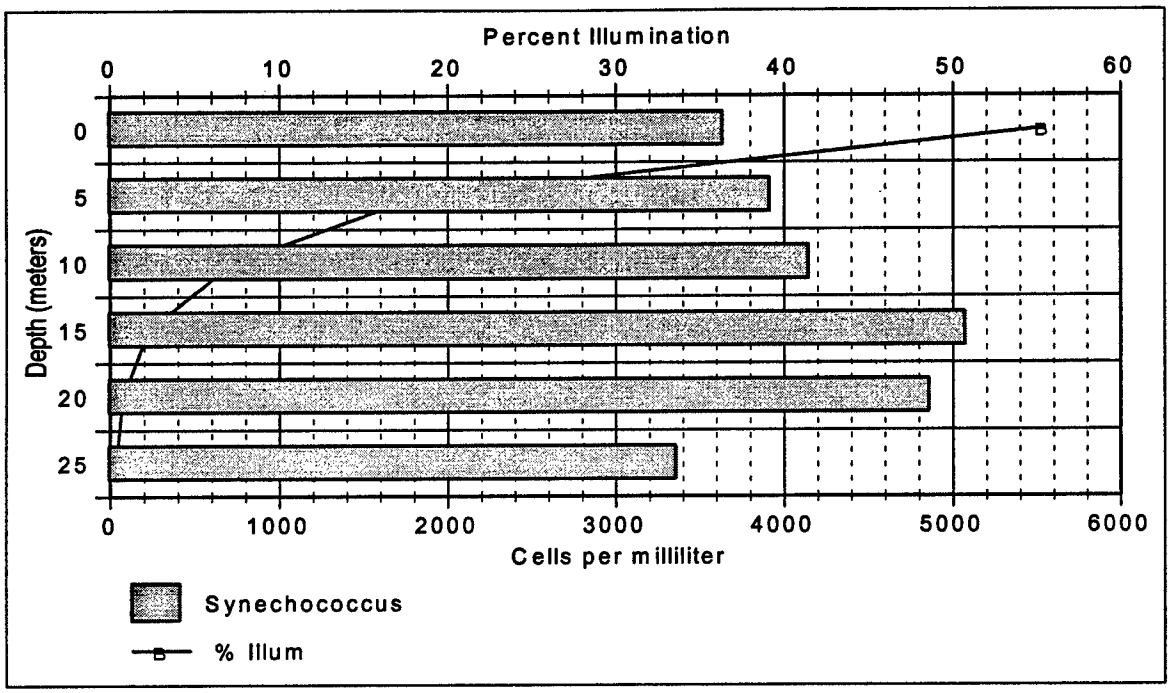

Figure 46

Dome 04 May *Synechococcus* & Percent Illumination Profile

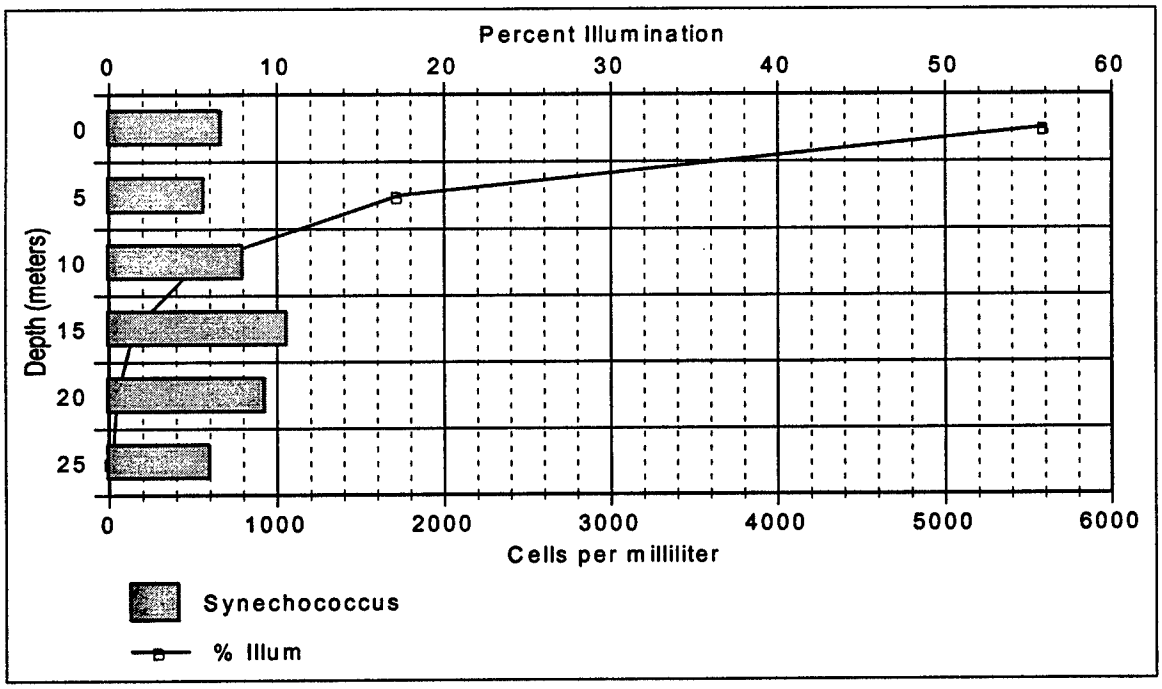

Figure 47

Dome 17 Aug *Synechococcus* & Percent Illumination Profile

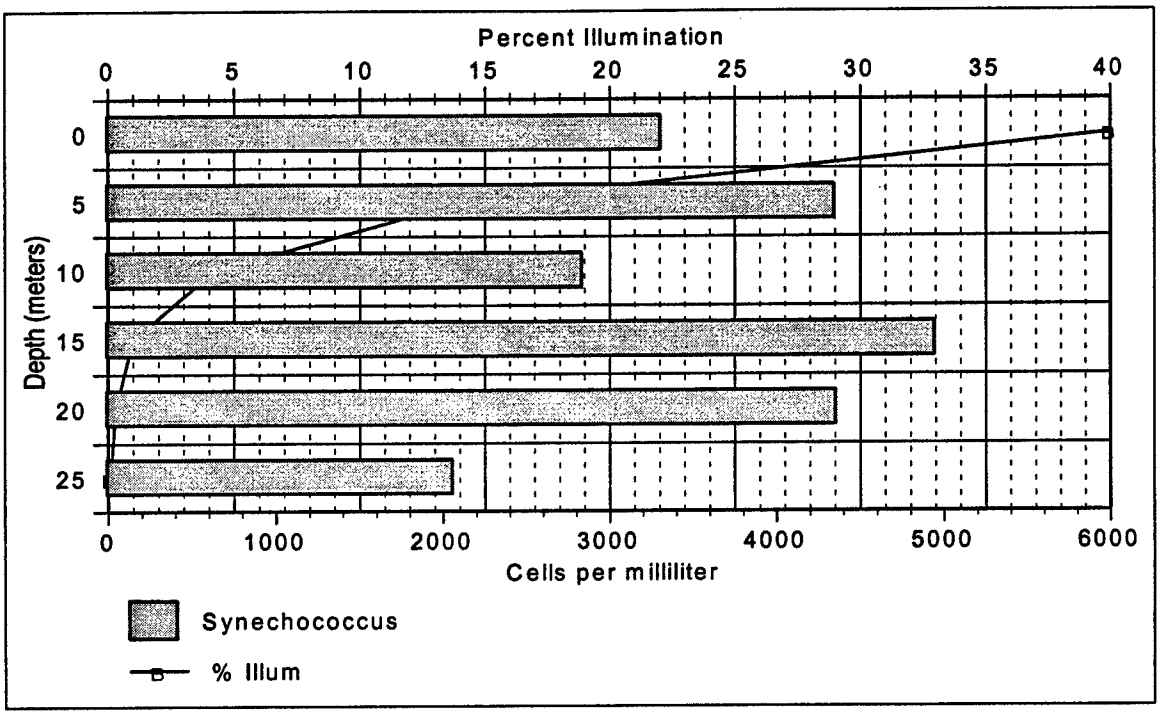

Figure 48

The greatest populations of *Synechococcus* were also found to occur at colder depths at or below the metalimnion. Figures 49, 50, 51 and 52 show that this pattern was the same for both sites at the beginning and the end of the study period.

Hague 04 May *Synechococcus* & Temperature Profile

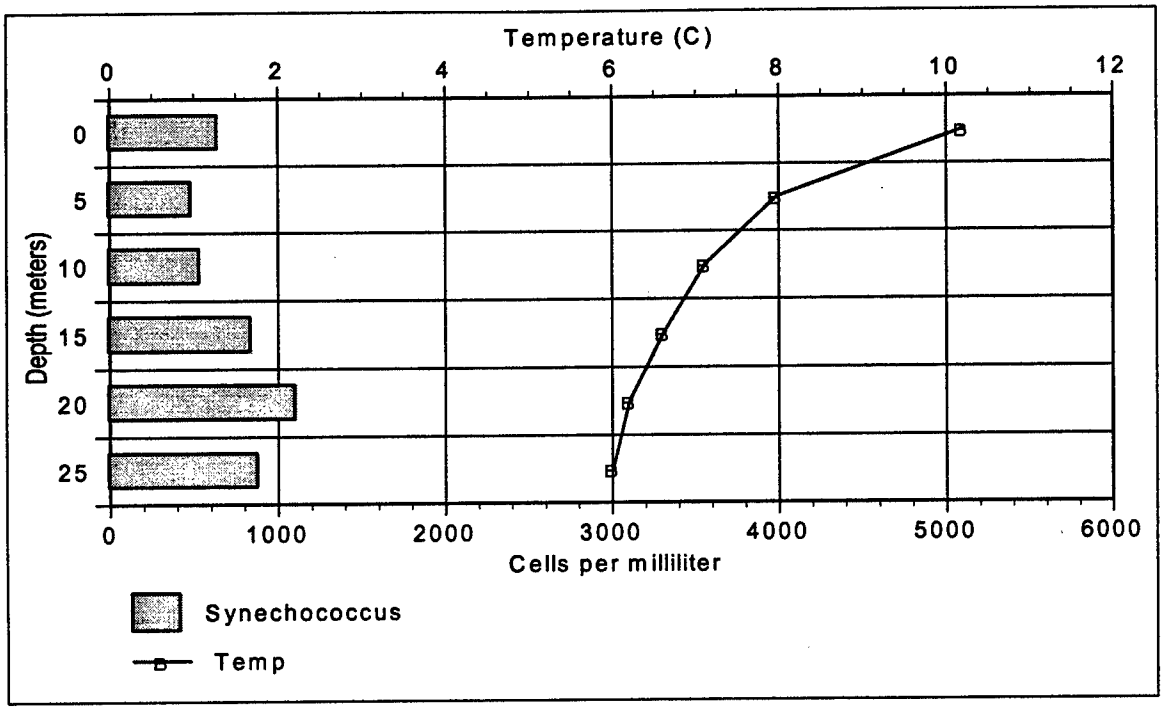

Figure 49

Hague 17 Aug *Synechococcus* & Temperature Profile

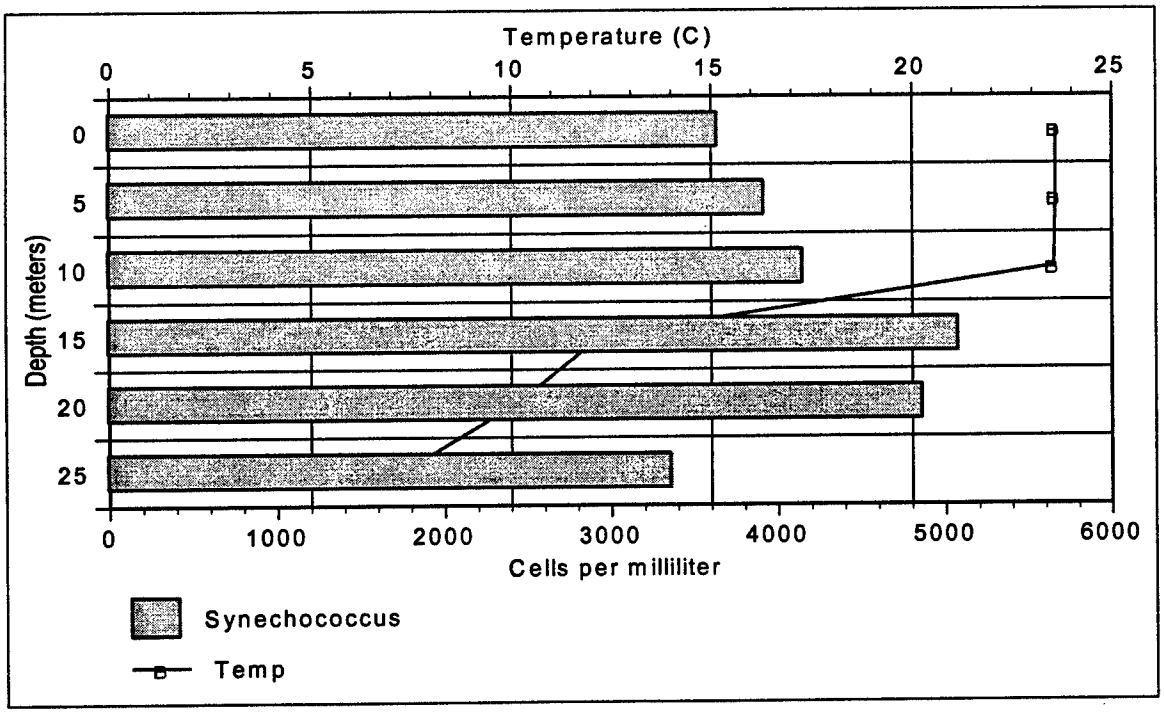

Figure 50

Dome 04 May *Synechococcus* & Temperature Profile

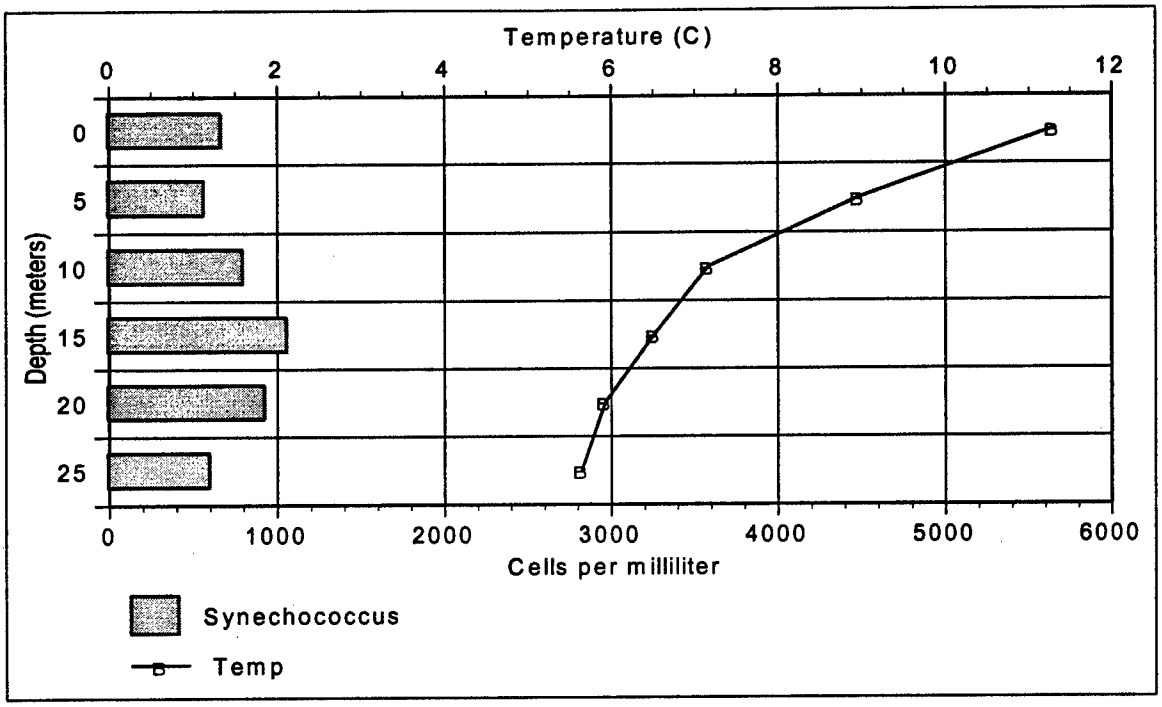

Figure 51

Dome 17 Aug *Synechococcus* & Temperature Profile

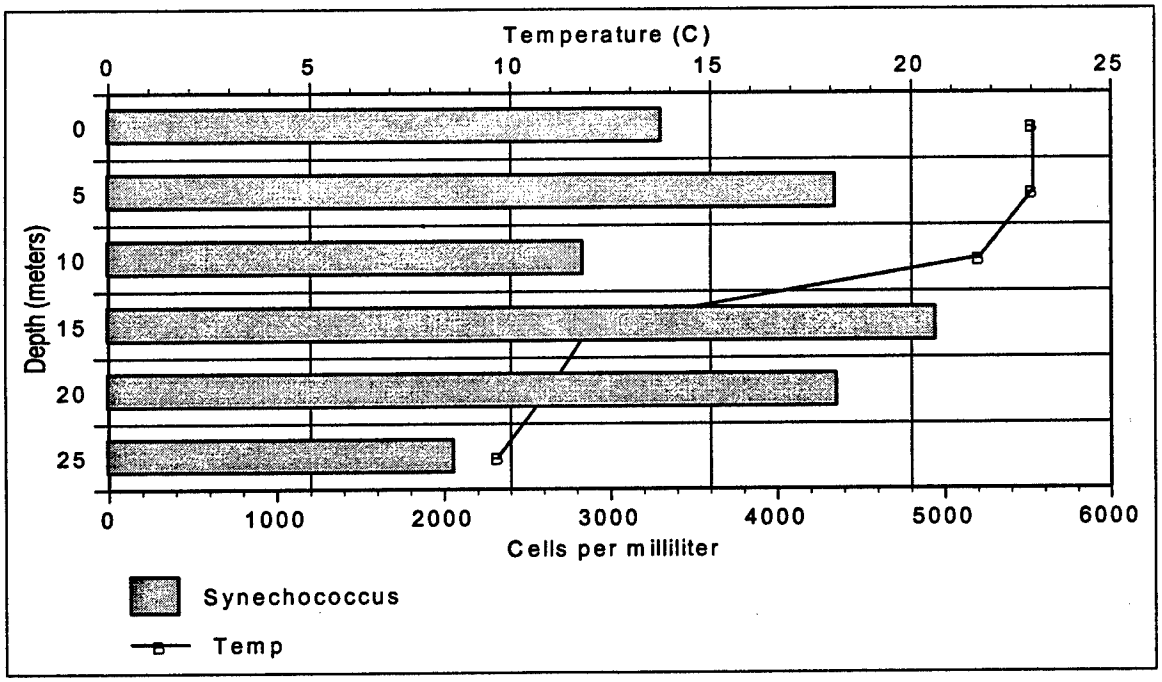

Figure 52

The results of the Secchi Disk Depth measurements are in accordance with the PEG Model of plankton seasonal progression (Sommer, 1989) and the seasonal progression outlined by Wetzel (Wetzel, 1975). The PEG model (Plankton Ecology Group) is a model of phytoplankton and zooplankton succession in an ideal lake. This model explains that at the beginning of the spring there is an abundance of nutrients, which with the increased sunlight causes a growth of phytoplankton. The Secchi Disk measurements from the early part of the season (04 May and 11 May 1998) show decreased water clarity (see Figure 2). This is due to this increase of phytoplankton. This increase in phytoplankton triggers an increase in herbivore grazing and as most of the phytoplankton is grazed or in the case of diatoms, run out of available silicate or phosphorus, Lake George then enters a period known as the clear water phase. This is also shown in the Secchi Disk depth profile (Figure 2) and corresponds to the periods 18 May 1998 and 26 May 1998 at Site Hague and Site Dome.

The PEG model then predicts an increase in large filamentous nitrogen-fixing cyanobacteria as a result of a decrease in available nitrogen. It does not address an increase in the small *Synechococcus*. No large increase in filamentous cyanobacteria was seen in Lake George during the sampling period. At this point with the larger phytoplankton having been consumed by the herbivores, the small *Synechococcus* are able to better compete for the limited nutrients in Lake George resulting in an increase in their population at both sites beginning in mid- to late-June (see Figures 43 and 44). This study period only continued until 17 August yet a decrease in the *Synechococcus* population could

already be seen and as the PEG model indicates is probably the result of decreased net primary productivity as a factor of reduced sunlight with continued grazing of *Synechococcus* by nanoflagellates.

A preliminary study of the growth rate of *Synechococcus* and the grazing rates on them was conducted using the dilution technique described for chlorophyll a by Landry and Hassett (Landry & Hassett, 1982). Water samples for this experiment were collected at 10 meters in depth from Site Dome on 03 August 1998. Results with and without addition of nitrogen and phosphorus are provided. The without nutrient addition experiment resulted in negative growth and negative grazing rates, - 0.246 day^{-1} and - 0.592 day^{-1} respectively. The with nutrient addition experiment resulted in positive growth and positive grazing rates, 0.102 day^{-1} and 0.278 day^{-1} respectively. This does lead one to the hypothesis that to achieve accurate growth and grazing rates additional nutrients need to be added to simulate naturally occurring nutrient additions.

Different physical and chemical variables in the water column can influence *Synechococcus* temporal and spatial distributions, which leads into the next segment of the discussion. This segment of the discussion concerns the comparison of *Synechococcus* populations at different sites to each of the chemical and physical variables measured in order to determine if there is any single measured factor which might show a linear relationship to the abundance of the *Synechococcus* in Lake George.

Utilizing linear regression each independent variable, chemical and physical factor, was plotted against its corresponding dependent variable, *Synechococcus*

population, for each site and depth. At Site Hague only three single variables showed any linear tendencies to *Synechococcus* population (see Figures 53, 54 and 55). They are Dissolved Oxygen, Dissolved Phosphorus, and pH. The R^2 values, which are a measure of how closely related an independent variable is to a dependent variable (on a scale of 0 to 1, 1 being directly related), are provided on each figure.

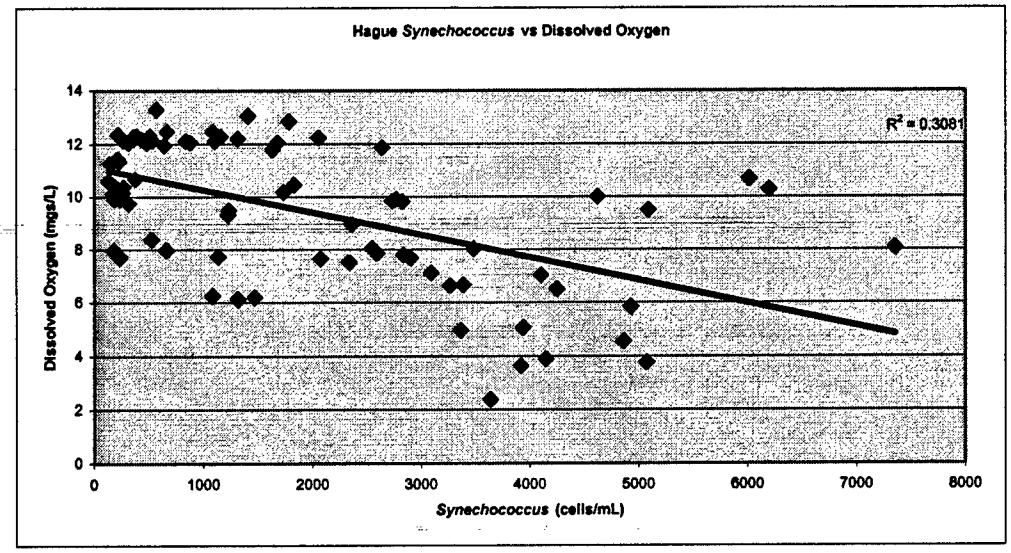

Figure 53

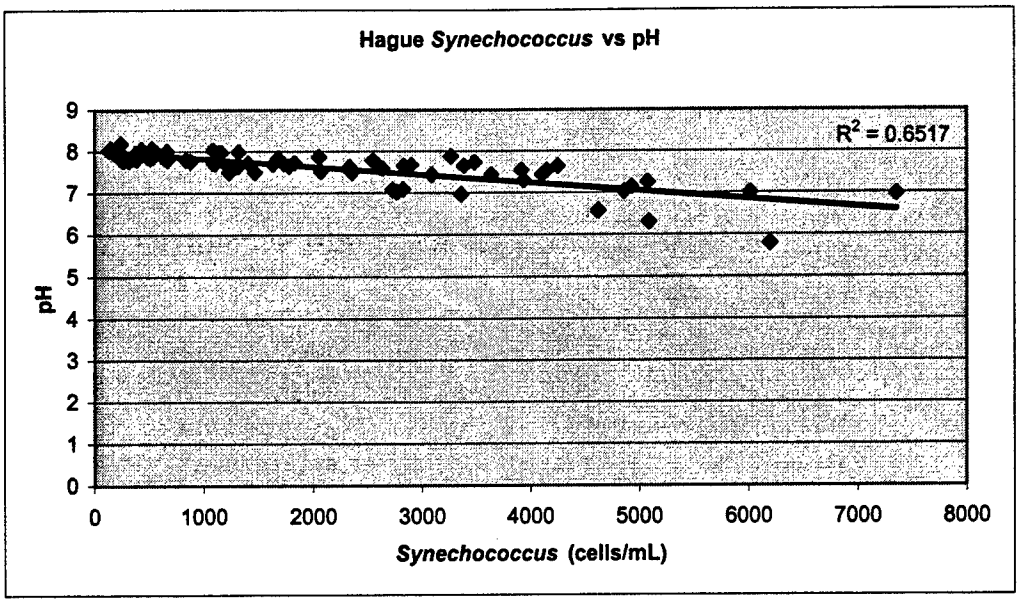

Figure 54

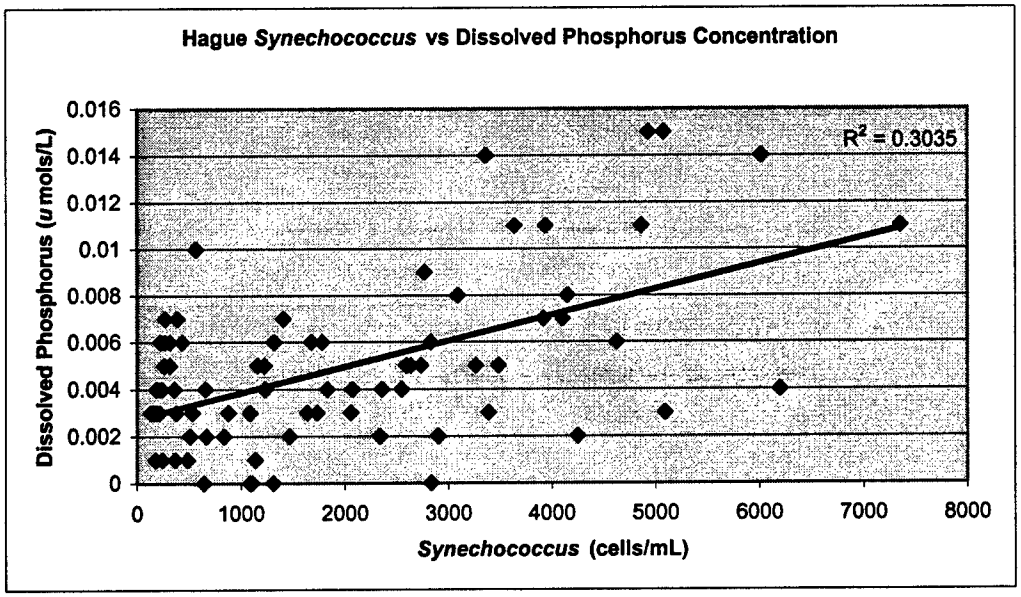

Figure 55

Of the three variables reported here, pH showed the closest fit using simple linear regression with a resulting R^2 value of 0.6517. Each variable measured (as discussed in Method and Materials) was applied in this same manner,

however R^2 values for all other variables were less than 0.1 and these figures are not shown.

The same linear regression analysis was conducted using the data collected for Site Dome in the southern basin. The same three variables (Dissolved Oxygen, Dissolved Phosphorus, and pH) showed the strongest linear relationships at this site also. The relationships can be seen in Figures 56, 57, and 58.

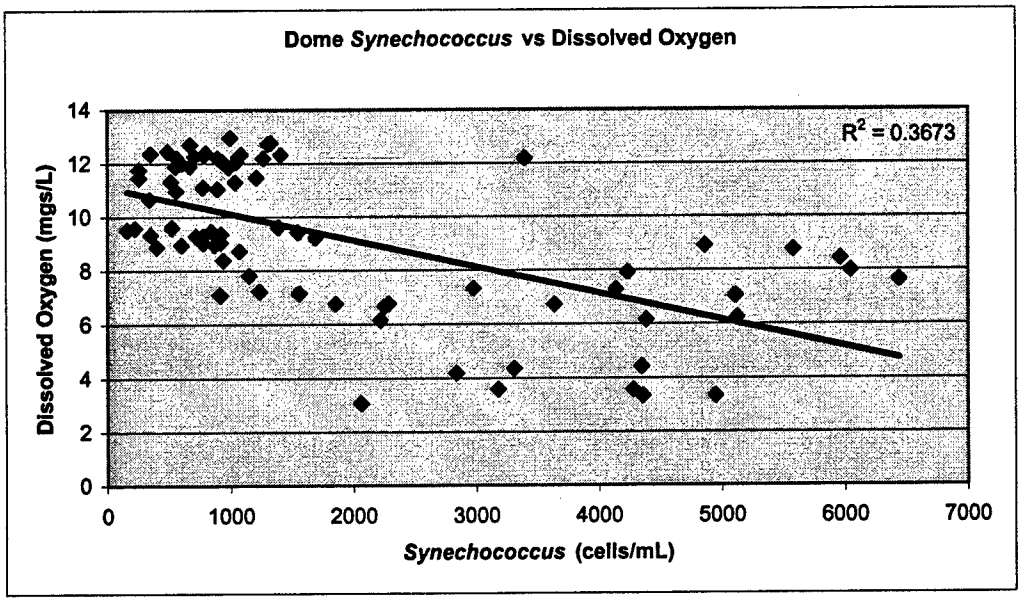

Figure 56

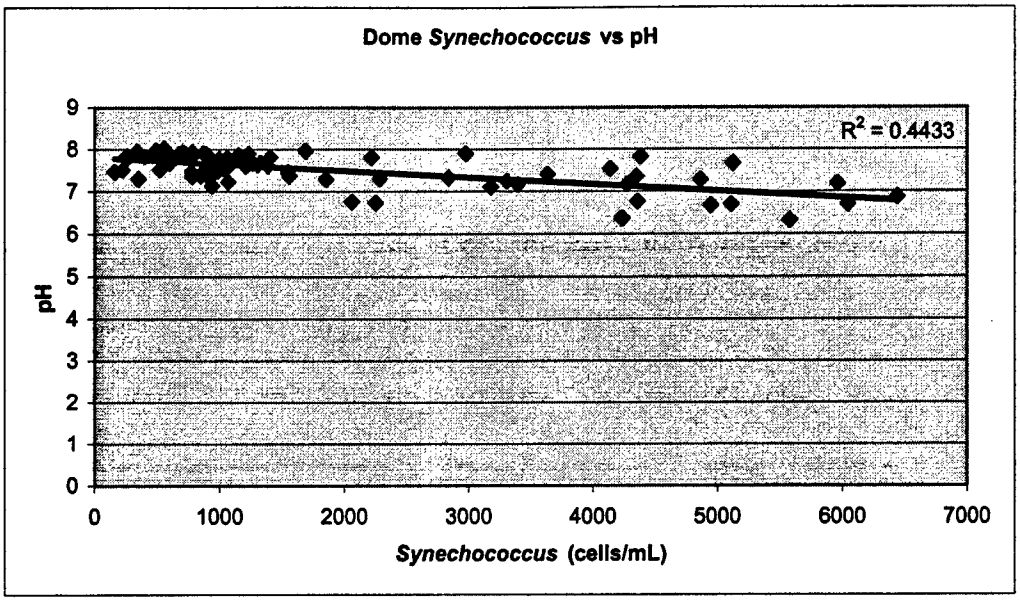

Figure 57

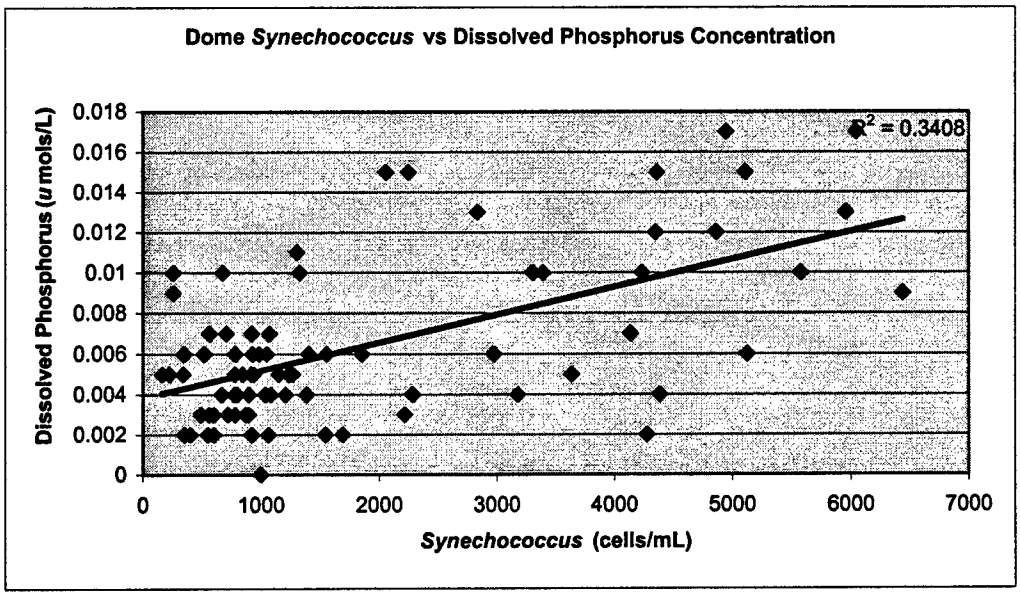

Figure 58

Similar to Site Hague, the linear relationship of all other variables to the corresponding *Synechococcus* populations was poor (R^2 less than 0.1). pH once again showed the strongest relationship with an R^2 value of 0.4433.

Since it is possible that more than one single variable could be controlling the temporal and spatial population dynamics of *Synechococcus*, the next step was to utilize multiple linear regression analysis and the Statistical Analysis Software program. This multiple linear regression approach was conducted by first combining all the different variables into one "full" model and then eliminating variables from the model utilizing partial regression plots of each separate variable. By elimination of the variables that do not contribute significantly to the model you are left with those variables with some direct relationship to the *Synechococcus* population numbers. This method was applied initially to the entire set of data independent of the particular sites (Hague or Dome). Using this multiple linear regression approach for all the data resulted in an adjusted R^2 value of 0.7539 (adjusted R^2 is the R^2 adjusted for degrees of freedom that is determined from the number of observations and number of predictor variables in the model). The resulting model equation for all data throughout the summer is:

$$\textit{Synechococcus}\ \text{(in cells/ml)} = 23016.8 + 32.7831[DEPTH] - 203.366[DO] - 35.8687[COND] - 2107.04[pH] - 1291.59[NH_4] - 8863.74[NO_2] - 3625.09[NO_3] + 331.483[DN] + 121858[DP]$$

The adjusted R^2 value utilizing all of the data is reasonable (0.7539), however based upon the information discussed earlier concerning the PEG model for an ideal lake it is important to examine the data based upon changes in the water column during the seasonal succession. The data set was split into two groups using the date of 08 June 1998 as the cutoff for the first set of data. As shown earlier in the paper the 08 June sample was selected because it was at this time that the clear water phase ended and the *Synechococcus* populations

began to increase at both sites and also to move up in the water column to the vicinity of the metalimnion.

When the data are separated by estimated date of the end of the clear water phase (mid-June), the resulting adjusted R^2 values for the data are 0.6145 for the period 04 May 1998 – 08 Jun 1998 and 0.8444 for the period 15 Jun 1998 – 17 Aug 1998. The resulting seasonal succession model equations for the entire lake are provided:

04 May 1998 – 08 Jun 1998 (adjusted $R^2 = 0.6145$)

***Synechococcus* (in cells/ml) = 918.346 + 14.0928[DEPTH] – 57.5818[TEMP] – 10.2262[DO] + 1.997[PERIO] + 6081.89[NO_2] + 5448.19[NO_3] –4754.59[NO_2/NO_3] – 28.1057[PN] + 5733.59[PP]**

15 Jun 1998 – 17 Aug 1998 (adjusted $R^2 = 0.8444$)

***Synechococcus* (in cells/ml) = 19114.2 – 217.140[TEMP] – 177.815[DO] + 17.9272[COND] – 2004.24[pH] – 1458.92[UREA] – 1682.08[NH_4] – 11483.4[NO_2] – 13970.9[NO_3] + 1316.51[DN] + 93325.2[DP] + 489.763[PN] + 9009.94[NO_2/NO_3]**

The adjusted R^2 values for the previous models demonstrate that the variables controlling *Synechococcus* population in the entire lake prior to the end of the clear water phase are less definable than after the end of the clear water phase. This makes sense when one considers that the lake becomes very stable in the mid-summer when the water column stabilizes with the formation of a metalimnion in the vicinity of 8-12 meters at each site. In the late spring and early summer the water column is still undergoing rapid warming in the shallower depths and the stratification has not yet been fully established. During this early

period there are still considerable nutrients found in the epilimnion and also a temporary sustained growth of the overall phytoplankton population that continues until the clear water phase. All of these result in a period of rapid change in the water column.

The next step was to examine each site separately considering this seasonal progression. The data set was first separated by Site (Hague or Dome) and then these data sets were further separated by the same seasonal succession dates (04 May 1998 – 08 Jun 1998 & 15 Jun 1998 – 17 Aug 1998).

Site Hague (04 May 1998 – 08 Jun 1998) (Adj $R^2 = 0.9064$)

***Synechococcus* (in cells/ml) = 29420.2 – 23.2828[TEMP] – 458.009[DO] – 26.4438[COND] – 2808.03[pH] + 324.379[Phaeo] + 853.244[NH4] + 267.996[DN] – 19.5192[PN] + 12238[PP]**

Site Hague (15 Jun 1998 – 17 Aug 1998) (Adj $R^2 = 0.8948$)

***Synechococcus* (in cells/ml) = 23420.5 – 174.619[TEMP] – 303.422[DO] – 2236.79[pH] – 591.239[UREA] – 1129.42[NH_4] – 8448.81[NO_2] – 5277.44[NO_3] + 554.240[DN] + 227447[DP] +297.777[PN] + 23175.1[PP]**

Site Dome (04 May 1998 – 08 Jun 1998) (Adj $R^2 = 0.8028$)

***Synechococcus* (in cells/ml) = 466.101 – 8.0112[PERIO] + 865.228[UREA] + 445.213[NH_4] – 3097.55[NO_3] + 3242.82[NO_2/NO_3] – 228.818[DN] + 11771.4[PP] – 19.4596[PN]**

Site Dome (15 Jun 1998 – 17 Aug 1998) (Adj $R^2 = 0.8616$)

***Synechococcus* (in cells/ml) = 22719.6 – 115.538[TEMP] – 158.023[DO] + 29.6624[COND] – 2928.01[pH] – 34.2246[PERIO] – 2207.63[NH_4] – 5163.10[NO_3] + 2270.99[DN]**

These models provide some evidence that the factors controlling the *Synechococcus* population at Site Hague are less variable then are the factors at Site Dome. Site Hague showed little seasonal variation between late spring/early summer and late summer (Adj R^2 values of 0.9064 and 0.8948 respectively). Site Dome showed more seasonal variation with Adj R^2 values of 0.8028 and 0.8616 for the same respective periods. It is interesting to note also that at each site and seasonal period different variables were found for the model equations. The evaluation of these multiple linear regression statistical models confirm some concepts already arrived at from general comparisons of the *Synechococcus* populations in the early summer versus the late summer. Just a simple comparison of the *Synechococcus* population profiles (Figures 43 and 44) demonstrated that at some date near the 08 June sampling date the clear water phase in Lake George ended. This clear water phase was followed by a period of rapid increase in *Synechococcus* total populations accompanied by a spatial shift in populations upward in the water column to the vicinity of the metalimnion. It seems the only way to truly find the trends in population dynamics is to use the approach of separating them along seasonal time periods utilizing the concepts from the PEG model. Following the clear water phase, a cyanobacteria, in this case *Synechococcus*, succession should occur and that is what is seen in Lake George. Based upon this assumption one has to disregard the first multiple linear regression method discussed in which all the data were grouped together across the entire summer. Even though the resulting adjusted R^2 values were not terribly low, the values were still lower than those found after dividing the data

based upon the end of the clear water phase. The statistical analysis of the data using the idea of separating it at 08 June 1998 resulted in much more accurate models of the conditions associated with the *Synechococcus* population dynamics at both sites.

Many of the variables are common to most of the model equations and some variables have no association to any model. The following chart shows all the variables from the split models and whether that variable had a positive or negative association with the projected *Synechococcus* population for that model.

	04 May 98 – 08 Jun 98		15 Jun 98 – 17 Aug 98	
	Hague	**Dome**	**Hague**	**Dome**
Depth				
Temperature	-		-	-
Dissolved Oxygen	-	-	-	-
Specific Conduct	-			+
pH	-		-	-
Percent Io		-		-
Phaeophytin	+			
Orthophosphate				
Urea		+	-	
Ammonium	+	+	-	-
Nitrite			-	
Nitrate		-	-	-
Nitrite/ Nitrate		+		
Particulate Nitrogen	-	-	+	
Dissolved Nitrogen	+	-	+	+
Particulate Phosphorus	+	+	+	
Dissolved Phosphorus			+	

Table 42

The statistical analysis and resulting model equations show that it is more than one factor that determines population densities of *Synechococcus* in Lake George. The limnological dogma that freshwater lakes are phosphorus limited is

a broad generalization of a more complex ecological process. The model equations do show that in the cases where phosphorus forms are included in the model the relationship is positive (i.e., increase in phosphorus is associated with increase in *Synechococcus*). This is not the case for nitrogen forms in which some forms have a positive effect and others have a negative effect on the models. It is interesting to note that pH was found in each model with the exception of the Dome model for the early summer and that Dissolved Oxygen was found to have a negative effect in each model. In each case where pH was in the model it too was negatively associated with *Synechococcus* populations. These two factors do correspond to the earlier simple linear regressions that showed the strongest relationships were with Dissolved Oxygen and pH. The build up of nitrogenous forms in the hypolimnion during the summer and application of Liebig's Law of the Minimum could contribute to the belief that it is not nitrogen that is limiting growth of *Synechococcus* in Lake George, but that does not imply it is phosphorus either. Not all possible factors were measured in this study.

Although Lake George is considered a pristine lake there is a significant microbial population in the water. The focus of this study was only on the cyanobacteria, but there are other microbes equally as important to the ecological processes of the lake. This study shows that some physical and chemical factors are more important than others in the dynamics of one of the primary producers in Lake George. This study has also shown that a new approach needs to be applied when determining what limits the growth of a

certain type organism in a lake. The lake has different seasonal patterns and these patterns affect the growth requirements of organisms differently. Perhaps phosphorus does limit some of the phytoplankton populations in the lake or perhaps another nutrient that was not measured controls the populations. In this study we looked at a considerable number of factors that might control cyanobacteria growth, but this study was not all encompassing. This study allowed us to eliminate some possibilities, however there may be other factors, such as trace metals, sulfate, or silicate or even grazing pressures that might be controlling the growth of the cyanobacteria or other phytoplankton.

It is important to learn as much as we can about the phytoplankton of lakes and oceans. The impact of humans on these microbial communities is only now being realized. As we affect these primary producers we affect everything above them in the food web. Just the data for Lake George shows that there is on average a greater abundance of *Synechococcus* and their required nutrients in the southern basin of Lake George. Is this a result of more human activity in the south or are there other natural factors causing this increase, such as greater stream input? Only more detailed studies of Lake George can answer this question. Cyanobacteria population dynamics can be used as a valuable measuring tool to help answer these questions.

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APPENDIX A

1997 Synechococcus Data:

Site Hague

Depth	04-Jun-97	18-Jun-97	02-Jul-97	16-Jul-97	30-Jul-97	12-Aug-97
0.1	534.75	354.72	745.09	1089.12	1732.62	7821.74
6	680.92	178.25	199.64	463.45	4081.99	8855.61
14	1696.96	1204.99	2278.07	1700.53	3985.73	5468.80

Table 43

Hague *Synechococcus* Profile - 1997

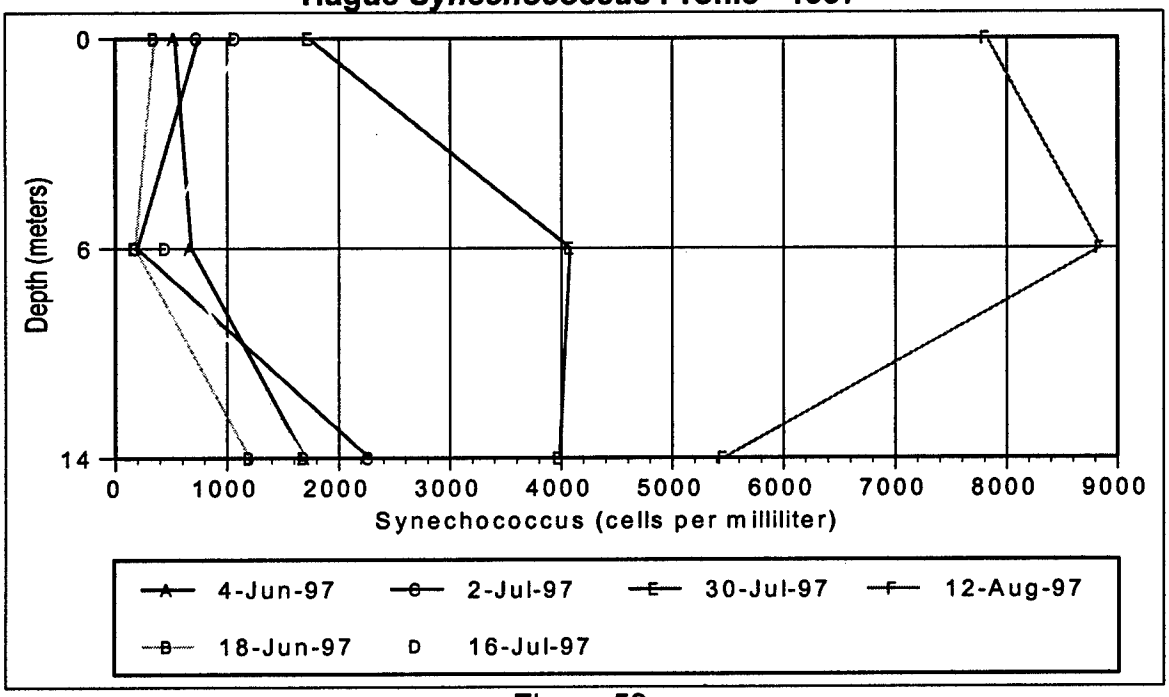

Figure 59

Hague *Synechococcus* Summer Succession - 1997

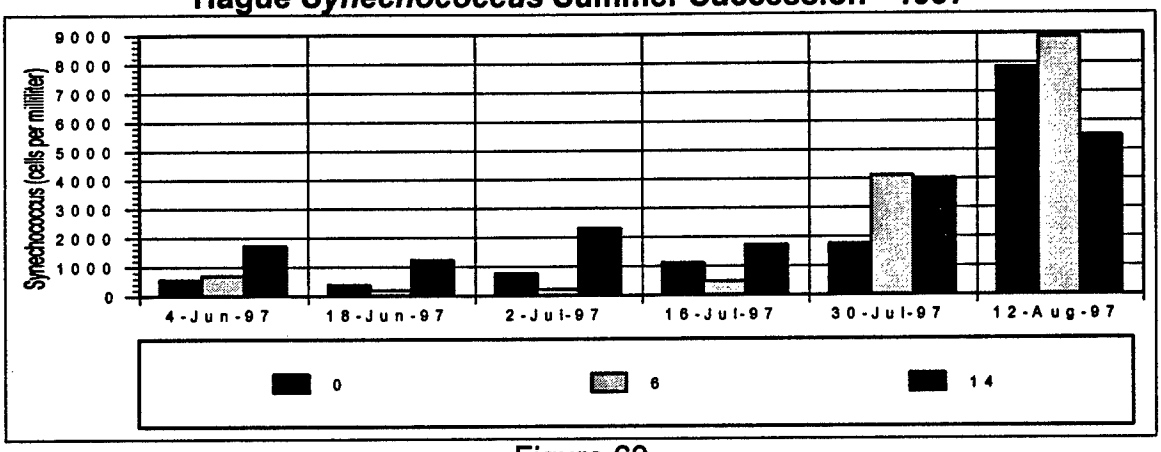

Figure 60

Site Dome

Depth	04-Jun-97	18-Jun-97	02-Jul-97	16-Jul-97	30-Jul-97	12-Aug-97
0.1	1001.78	1023.17	417.11	955.43	3923.35	5572.19
2.5				1122.99	2934.04	7490.19
4	1721.92	919.78	720.14	1672.01	2916.22	8295.90
8				3707.66	3169.34	4755.79
12	2256.68	4513.36		3440.28	5379.67	3026.73
14			5493.76	1910.87	4449.19	6253.11

Table 44

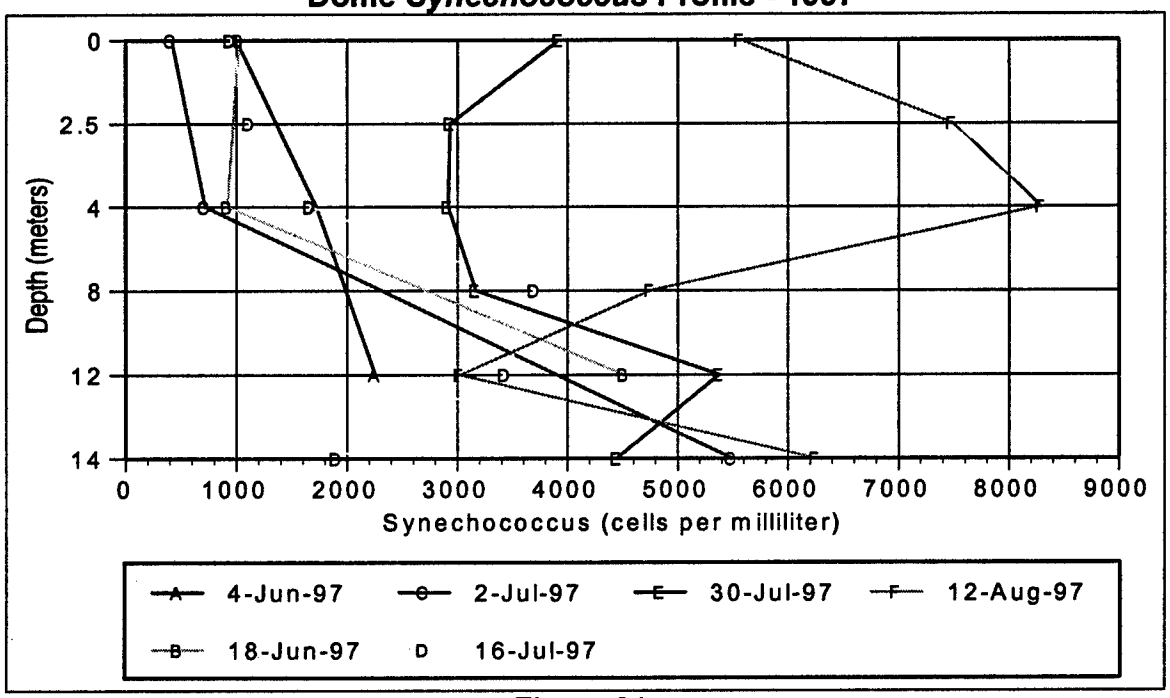

Figure 61

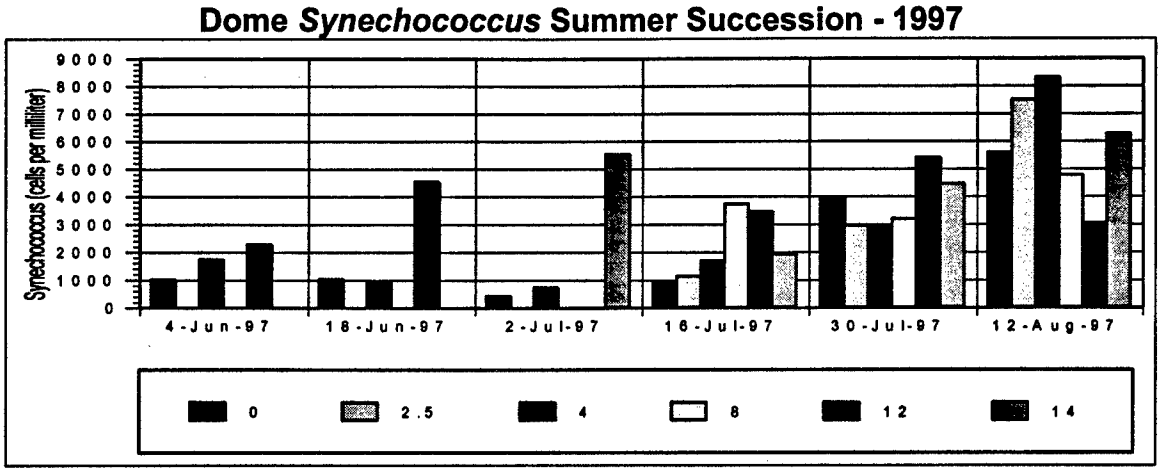
Dome *Synechococcus* Summer Succession - 1997
Synechococcus (cells per milliliter)
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
4-Jun-97
18-Jun-97
2-Jul-97
16-Jul-97
30-Jul-97
12-Aug-97
0
2.5
4
8
12
14

Figure 62